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PREFABRICATED HIGHWAY PAVEMENTS (SBORNYE POKRYTIIA AVTOMOBIL'NY--ETC(U)
JAN 77 V M MOGILEVICH, E N DUBROVIN

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PREFABRICATED HIGHWAY PAVEMENTS

V.M. Mogilevich, ed.

FEDERAL HIGHWAY ADMINISTRATION
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PREFABRICATED HIGHWAY PAVEMENTS

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The book is intended for students of institutes of higher learning, learning to be "Highway" specialists, and also may be used for engineering-technical workers, employed in the field of road planning and road construction.

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S.V. Konovalov, E.Ya. Turchikin

Reviewed by:Department of "Construction and Exploitation of Automobile Roads" Saratovsk Polytechnical Institute (Department Head V.V. Shvatko); Doct. tech. science Prof. I.A. Zolotar (Leningrad Military Order of Lenin Academy of Logistics Systems and Transport).

Foreword

In addordance with the decisions of the XXIV convention of the KPSS in the current five year plan, the theme of road construction was raised a great deal. The increase of road expanses in yearly operation was provided for not only by increasing capital investments, but also by better use of the productive capacities of road-building organizations switching over to a continuous, year-round process of work, increasing productivity, and this, in turn, is closely connected with a further introduction of new techniques into road building.

Automobile production has greatly increased, which brings with it an increase and renewal of the number of automobiles in the country. The new types of automobiles are characterized by high loads on the axis, an increase in the specific pressure on the road pavement and high speeds. In connection with the increase in the number of automobiles used, there is an increase in the intensity of traffic.

Under these conditions, it is necessary not only to increase the total expanse of the highway network, but to increase its quality essentially. Attention should be paid especially to working out new and improving existing constructions of road surfaces, as well as to the organization and technology of their construction. The condition of the road surface and its parameters to a considerable degree determine the conditions for the movement of automobiles.

One of the most promising directions in the field of planning and constructing road covers is the use of prefabricated constructions. The transition from constructing monolith pavements and bases to installing them from elements made beforehand makes it possible to fundamentally change the organization of the construction process and to increase the effective use of labor and material resources.

The development of industrial bases of construction and the growth of mechanical equipment and road construction organization in the past few years created favorable conditions for the widespread use of prefabricated constructions in road building. Many leading road-building organizations successfully build and use prefabricated covering of different designs and of different designations. We must await further great increase in the volume of constructing prefabricated road covers and bases.

In the present educational manual, Prof. V.M. Mogilevichem wrote the foreword, the introduction, § 1,5,6, 13-17, 21-25, 27,36,38; doctoral candidate of technical sciences S.V. Konovalov wrote the §32-35, 40 and the appendix; doctoral candidate of technical sciences S.V. Konoval and candidate of technical sciences M.S. Koganzon wrote § 9-12,; doctoral candidate of technical sciences E.N. Dubrovin, E.Y. Turchichin and Yu. V. Starostin wrote § 3,4,7,18-20, 28-31,

37,39; prof. V.M. Mogilevich, E.N. Dubrovin and E.Ya. Turchxin wrote § 26; V.M. Mogilevich and S.V. Konovalov wrote § 2,8.

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The authors thankfully accept all remarks directed toward improving the educational manual and will take them into account in further studies.

Introduction

Prefabricated pavements have been used for a long time in road construction. Stone slabs were used in Ancient Rome, in ancient Greece, Egypt and other countries long before the beginning of our era. In the Middle Ages in Europe, they built gage roads with a cover made of large stones or slabs preferably of rectangular shape.

Preparing and procdssing the rock slabs required great outlays of manual labor. Great difficulties arose in stacking the heavy slabs on the cover. The absence of machines, which would alleviate preparing and placing the rock slabs, especially ones of large dimensions, and the necessassity of doing the work manually, seriously hampered the development of building prefabricated pavements. The muscular force of a man determined the weight and, consequently, the dimensions of one installed slab. The result of such a limitation was a general distribution of the cover from fine rubble, cobblestone and paving block bridges and bridges made of wooden blocks.

At the beginning of the 20th century, concrete slabs were started to be used in a series of countries for road pavement. The use of cement concrete greatly reduced the labor consumed in preparing the slabs and made it possible to prepare the slabs with different contours. However, the absence of mechanical means for laying them down initially hampered the use of slabs of large dimensions. In the majority of cases, the area of one slab did not exceed 0.10-0.25 m^2.

In the Soviet Union, the making of prefabricated road covers from concrete slabs was proposed in 1928 by Prof. I.A. Kirienkp. The slabs had a hexagonal shape with a dimension of one side of 30 cm. Experimental sections from these slabs were built in Kiev and in Moscow. The first sufficiently developed and well-founded proposal for the use of large-dimensioned slabs (3.0x3.5 m) for the construction of a pavement was made by Prof. A.K. Birulya in 1939.

At the time of the Great Civil war, prefabricated covers (preferably of wood) were used for temporary military roads.

Considerable investigatory and planning work in the field of working out new design slabs, the use of new materials and improving the technology of installation was done in the Soviet Union in the post-war years by a number of educational and scientific-study institutes (KADI, XADI, MADI, SibADI, Union-DorNII, VZISI, Mosinzhproekt etc). Large volumes of experimental construction of prefabricated pavements was done by different industrial organizations. All this guaranteed a real possibility for the use of prefabricated pavements in road building.

At the present time, prefabricated highway pavements, primarily made of concrete and reinforced concrete slabs, were successfully installed on municipal streets and on individual parts of automobile highways in the USSR, the USA, the Federal Republic of Germany, and other countries. The list of materials utilized is rather long. Along with concrete and reinforced concrete for making the slabs of prefabricated pavements, they also use silicate concrete, various bituminous-mineral and asphalt-concrete mixtures, metals, synthetic material, and so on. The area of constructed prefabricated pavements only of the main types is measured in hundreds of thousand of square meters. More characteristic examples of the construction of prefabricated pavements are examined below in corresponding chapters of the manual.

Prefabricated bases of road toppings have also been widely used. In the Soviet Union, large volumes of work in constructing bases of reinforced concrete slabs was done in Leningrad. Here, 100,000 m^2 of prefabricated bases were constructed in 1965 alone. Work on their construction was done in the course of the entire year (i.e. in the winter at below zero temperatures).

In the Urals and in Western Siberia, prefabricated bases from bituminous-mineral slabs were installed on roads of the IInd and IIIrd technical category. The manufacture and their installation is carried out preferably in winter.

Prefabricated pavements are also widely used on detours and on temporary roads of special designation (timber-carrying, industrial, etc). Up to 1967, more than 600 km of prefabricated reinforced concrete pavements [37] were constructed on the wood-carrying roads of the Northern European part of the USSR alone. In Moscow, in 1964, the area of prefabricated pavements on temporary roads amounted to 350,000 m^2.

However, despite the great successes in the field of planning and constructing prefabricated pavements of different types, their use is still not widespread, especially on roads of the above technical categories. To a considerable degree, this is explained by the fact that the advantages of prefabricated pavements are still not being utilized to full measure. The designs of installed slabs, their joining, the technology of installation differ very greatly. Up to the present time, there are still no clearly approved recommendations in this area.

Monolithic road toppings are usually installed on contemporary automobile roads. They (especially with pavements of the improved type) respond to the requirements for heavy and fast movement of automobiles in the majority of cases to a sufficient degree with corresponding quality. But the monolithic pavements, together with the essentially positive qualities, have a series of constructional and technological shortcomings, especially sharply manifested in carrying out work in winter, when constructing in densely populated areas and in other complex conditions.

When building monolithic pavements of the improved type, the more demanding and labor-consuming operations in processing rock materials are devoted to its installation in the road topping and compacting, which must be done under conditions of strict observance of the time and temperature regime. The periods for carrying out the work are limited to the necessity of installing and compacting hot and warm asphalt-concrete and bituminous-mineral mixtures until they cool off. The technology and the quality of work in constructing monolithic, improved pavements to a considerable degree depend on the weather-climate conditions. The performance of work is especially complex under winter-time conditions. At the present time, work is practically not done in constructing monolithic improved pavements at temperatures below (-10°)-(-15°). Assuring construction with bituminous-mineral (hot and warm) and cement-concrete mixtures is carried out from the plants, having relatively small supply zones in connection with limited periods of time for transporting the mixtures.

The technological complexity of carrying out the work complicates the organization of the construction and lowers the effectiveness of utilizing the labor and material-technological resources. In the summer time, it is necessary to concentrate a large number of workers and mechanization facilities on the road. Discontinuing work in the construction of pavements in the winter time involved forced idle time of the asphalt-concrete and cement-concrete plants; in addition, qualified working personnel, factory maintenance men and paving equipment have to be transferred to other work during this period.

The essential shortcoming of monolithic, cement-concrete pavements is the impossibility of opening traffic for them in the period of time necessary to achieve concrete with a given strength.

Monolithic, improved pavements (asphalt-concrete and cement-concrete) cannot be dismantled and used repeatedly. The materials used for their dismantling sometimes may be used for constructing less essential layers of road topping bases. But the investments in their preliminary reprocessing are extremely great and thus repeated use of these materials is not always economically justified.

Monolithic and improved pavements are completely destroyed in carrying out constructional or repair work of different communications situated under the road lining (water lines, connection cables etc). Their loosening and retraction as well as the subsequent construction on the strip of destroyed new road toppings require considerable investment. The site of the opening is always on the general surface of the monolithic covering and reduces the quality of the entire road topping.

The listed shortcomings of monolithic, improved pavements are eliminated to a considerable degree by replacing them with prefabricated monolithic designs.

The technology of carrying out the work is changed principally in the construction of prefabricated pavements which, in turn, makes it possible to improve the organization of the entire constructional process and to guarantee more effective utilization of the labor and material-technological resources. A redistribution of the volumes and types of work takes place between the constructional sources on the road and production plants. As a result of the transfer of a series of complex technological operations to plants doing prefabricated construction, the carrying out of the work directly on the road is greatly simplified. Energy-consuming processes in mixing, processing and compacting different discrete materials or their mixtures are excluded from the technological process on the road. The constructional work is almost completely reduced to assembling work. Thanks to this, their labor expenditure and energy expenditure are curtailed, the required number of workers and machines occupied directly on the road is reduced. By way of orientation, it can be assumed that with the replacement of monolithic pavements with prefabricated ones, the consumption of labor on the road will be reduced by 35-50%.

The technological operation in making the composite elements for prefabricated pavements is carried out in special plants or proving grounds. The conditions for carrying out the work at these plants guarantee the possibility of using more perfected equipment, complex mechanization and the automation of technological processes, as well as more favorable working conditions (compared with those in the field). In the final analysis, there is an increase in labor productivity, an increase in quality and a reduction in the net cost of completed production.

At specialized plants, the slabs for prefabricated pavements are manufactured during the entire year, independent of weather and climate conditions. This also reduces their cost and reduces the consumption of labor and energy per unit of production.

Prefabricated pavements made of finished slabs can be built during the course of an entire year, making use of unfavorable weather and climate conditions: fall, winter and spring. The transition to continuous, year-around construction facilitates decreasing its time periods and provides a considerable economic effect.

In the majority of cases, with prefabricated pavements it is possible to open it to traffic directly after laying the slabs. This is especially valuable in constructing pavements on city streets, on narrow, long dams and in other places where constructing detours is difficult.

The majority of designs of prefabricated pavements permits repeated use. They can be disassembled and then repeatedly assembled at the same place or transferred and used on other objects. This feature of prefabricated pavements is especially valuable under the exploitation conditions of city streets, where road toppings are frequently broken up for work in constructing or repairing underground pipelines. The possibility of multiple use of prefabricated pavements guarantees a high technological and economic effectiveness of their use in the construction of temporary roads of different designations and their use.

A very essential positive characteristic of building prefabricated pavements is the absence of technological limitations when using finished slabs and in addition hauling them over long distances. The limit distance for hauling finished slabs is determined by economic considerations and the presence of transportation means. With year around manufacturing of the slabs, it is possible to transport them to the place of use in the course of an entire year. This circumstance greatly widens the boundary of the factory supply zones, making slabs for prefabricated pavements.

In the practice of road building, cases are known of hauling slabs by railroad and water transport for several hundred kilometers.

Together with a whole series of positive features, prefabricated road pavements have certain shortcomings.

The basic ones are as follows:

the large number of joints (seams) between the slabs, which to a certain degree impairs the smoothness of the pavements;

the design of the seams used at the present time in a large number of cases does not sufficiently guarantee the transfer of a load from one slab to the other;

the necessity of taking recourse to non-standard slabs for paving (or going over to laying monolithic concrete) on small curve radii;

great expenditure of equipment;

-high constructional cost price;

the absence of special machines for laying the slabs (at the present time, in the majority of cases they use standard cranes, which may not provide accurate laying of the slabs and their tight fitting to the base).

The imperfection of the equipment used lowers the quality of the work and the productivity in laying the slabs. All these shortcomings, and also the small number of plants specializing in making these designs to a considerable degree limit the propagation of prefabricated pavements under contemporary conditions.

Nevertheless, despite all the listed shortcomings and the difficulties of introduction, prefabricated road pavements are progressive constructions. Many problems of a design, technological and organizational character in the construction of road facings can be solved more successfully when prefabricated constructions are used. Their use guarantees full industrial making of the pavements (bases) and to a considerable degree does away with the seasonal nature in carrying out road construction work.

The technical and economical effect obtained from using prefabricated pavements to a considerable degree depends on the correct selection of the place and time of their construction.

Prefabricated pavements can successfully compete with monolithic ones in the following conditions:

on city streets with intense traffic;

on parts of automobile roads layed down at places where the building of detours is difficult (on swamps, in the limits of irrigated or other especially valuable agridultural pieces of land (etc).)

when organizing the construction of road toppings under winter conditions (especially in regions with a short summer building season);

when building temporary roads with a limited time of exploitation;

when it is possible to organize construction of the slabs directly in the region where the road is being constructed in existing plants of the construction industry with a high level of mechanization and production automation.

In each concrete situation, the final decision in selecting prefabricated or monolithic pavements (bases) must be based on careful technical-economic comparisons of the possible variations.

The area of using prefabricated covers and the annual volume of their construction will constantly increase as construction of the slabs is improved, with the organization and technology of their manufacture and installation, and also with the working out of new and improved essential mechanization means used for laying the slabs.

Chapter I

Design of Prefabricated Highway Pavements

1. General Information

Prefabricated pavements are installed on highways of general use of the Ist, IInd and IIIrd technical category, on city streets, on squares, on aeroports, roads of special designation (inside plants, inside stone quarries, etc), and also on different temporary roads (building, timber-carrying, etc.). Moreover, prefabricated pavements are used on sidewalks and different park roads to guarantee the pedestrian traffic.

On highways, depending on their designation, technical category and traffic intensity, the designs of prefabricated pavements may be:

continuous, covering the entire area of the travelled part; gauge, covering only a narrow strip in the limits of the travelled part for strict fixing of the traffic of wheeled automobiles.

Continuous pavements are installed on highways of general use, of special designation with intense traffic, on roads with mixed traffic make-up (light automobiles, tractor and trailers, motorcycles), and also on urban streets. Gauge pavements are usually installed on temporary roads with a small amount of traffic. In a series of instances, gauge pavements are installed one-way with passing of the meeting automobiles on special widened parts. In the case of a high degree of traffic intensity (and on some roads of special designation), gauge pavements are installed two-way.

Schemes of the different designs of prefabricated pavements for highways are shown in Fig. 1.

According to the conditions of subsequent use, prefabricated pavements may be classified as prefabricated and prefabricated-sectional.

Prefabricated pavements are installed once. Usually, such pavements are installed on permanent roads in general use. In the process of normal exploitation, they are not subjected to dismantling. In individual cases, prefabricated pavements may be taken apart and then again restored by repeated installation of separate slabs. Such transferring of rigid prefabricated pavements is possible on city streets with work being performed in laying or repairing underground lines.

Dismantling of prefabricated pavements is carried out also with the repair of individual small sections. In this case, destroyed slabs are removed and replaced with new ones. Slabs without essential damage, but having a great deal of settling and shifting, are lifted up and, after adjusting the base, are again installed in place.

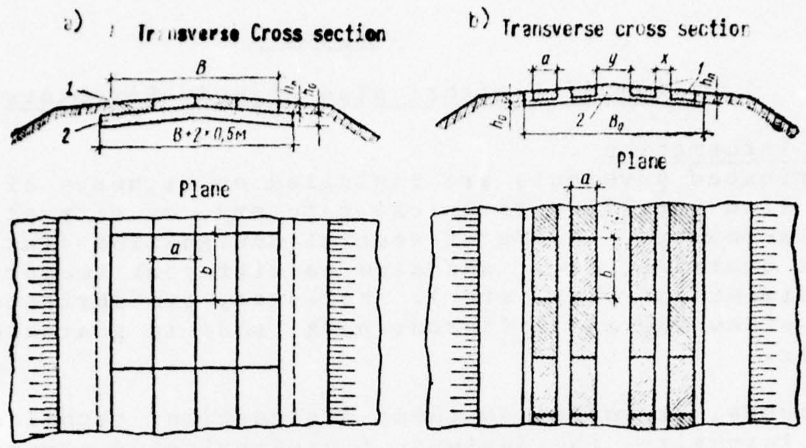


Fig. 1.--Schemes of the designs of automobile highway prefabricated pavements: a-Continuous prefabricated pavement; 1-Slabs of the prefabricated pavement; 2-Base; B-width of the travelled part (usually B=4a or 2a=7.5 m and more); a,b-dimensions of the slabs in the plane; a = B/n; n is a whole number; h_π is the thickness of the slab; h_0 is the thickness of the base layer; b-two-way gauge prefabricated pavement; 1-slabs of a prefabricated gauge pavement; 2-base; a-width of the gauge equals the width of the slab; b-length of the slab; h_π is the thickness of the slab; h_0 is the thickness of the base layer; y is the width of the track spacing usually equal to 1.0-1.5 m; x is the width of the area between the tracks usually equal to 0.7-0.9 m; B_0 is the width of the base layer (B_0 = 4a+2x+y+2x0.3 m).

In the case of a high degree of wear or damage to all (or many) of the slabs, the prefabricated pavement is expediently not dismantled, but is used as the basis for laying down the layer of another covering. The new pavement may be either monolithic (made of bituminous-mineral or asphalt-concrete mixtures), or prefabricated. In the latter case, according to the condition of the old pavement, it is necessary to first install a levelled layer of sand, of processed bitumen, dry cement-sand mixture or other suitable materials.

Prefabricated-sectional pavements are intended for repeated installation and dismantling on different temporary roads. Their exploitation periods fluctuate within wide limits, from a few days or a week to several years. In the case of slabs for prefabricated-sectional pavements, the constructional installations for clamping and lifting with crane equipment must be protected from damage for the entire time the slabs are in service.

The slabs of all types of prefabricated pavements are designed for temporary transportable loading and are checked for installation stresses, i.e. stresses emerging in the process of their installation. Slabs of prefabricated-sectional pavements are also checked for stresses emerging with their dismantling. It must be taken into

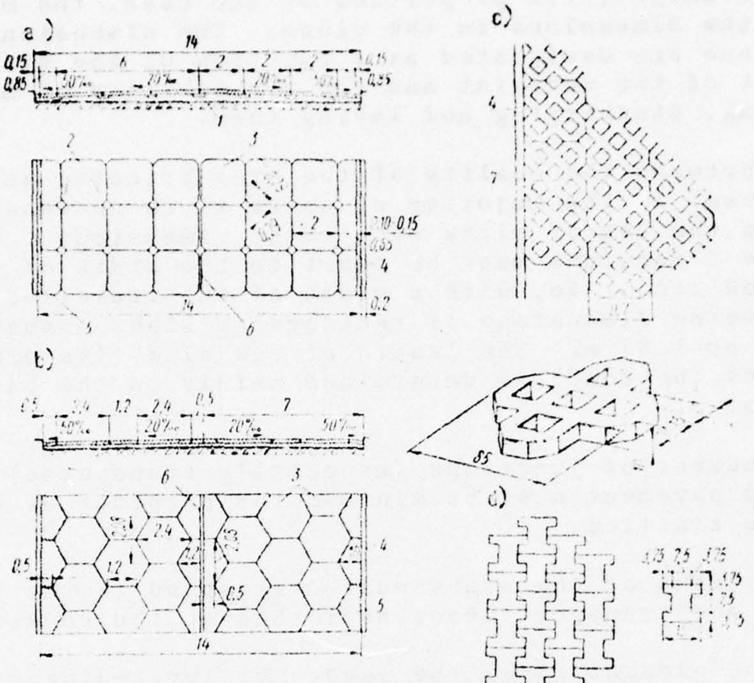


Fig. 2.--Prefabricated pavements made of different shaped concrete slabs: a-of square slabs with cut angles (Moscow, 1951); b-of hexagonal slabs (Moscow, 1954); c-of cross-shaped slabs with openings (Germany, 1940); d-of slabs with T-shaped profile; 1-concrete linings with a dimension 0.5x0.5x0.1 m under the junction of pavement slabs; 2-place where the slabs were joined with welding; 3-concrete slabs: square with a dimension 2x2x0.18 m, and hexagonal with a side 1.2 m and a thickness 0.16 m; 4-curb; 5-filling with monolith concrete (installation of half-slabs is also possible); 6-longitudinal temperature joint; 7-cruciform slab with aperatures (after laying the slabs, the openings are filled with gravel or crushed stone).

consideration that with large couplings of the slabs with the base, these stresses may be greater than those which emerge with the movement of automobiles.

Slabs of different dimensions and shapes in the plane are used for installing prefabricated and prefabricated-sectional pavements. Maximum propagation is obtained with rectangular slabs of simple contour.

In a series of cases, slabs having a hexagonal shape are used for installing coverings on squares, wide streets and airports. Cases are also known of using slabs with round, cruciform and other complex contours (Fig. 2).

The thicknesses of the slabs are determined as a function of automobile weight, the properties of the base, the material of the slab and the dimensions in the plane. The dimensions of the slabs in the plane are designated as a function of the width of pavement, the nature of the material and the availability of mechanical means for loading, discharging and laying them.

To increase the quality of the prefabricated pavement (primarily its evenness) in the majority of cases it is necessary to orient oneself to the use of slabs with large dimensions. Moreover, their transverse dimensions must be short to the width of the travelled part of the road. So, with a width of the travelled part of 7.5 m, the transverse dimensions of rectangular slabs assume dimensions of 3.75 m or 1.87 m. The length of the slab (its dimension along the axis of the road) is determined mainly on the basis of two requirements:

the number of junctions (especially transverse) in the prefabricated pavement must be minimum for purposes of convenience of automobile traffic;

the weight of the slabs must correspond to the lifting capacity of cranes and transport means available at the construction site.

At the present time, the length of large-dimensioned road slabs reaches 6 m and more. So, concrete reinforced slabs of the series PDG and PAG-XIV have a length of 6 m. When installing such slabs, the transverse joints on the pavement are spaced no more frequently than the transverse compression joints on conventional cement-concrete pavements. The increase (in some cases) of the number of longitudinal joints is practically not reflected in the conditions of automobile traffice, since the wheels do not intersect the longitudinal joints or they intersect at sharp angles which do not result in perceptible impacts. Thus, joints having the form of an extended rectangle are always installed with the long side along the road.

Increasing the dimensions of the slabs leads to increasing their weight and requires the use of high-powered lifting and installation mechanisms. Moreover, with large dimensions of the slabs, it is difficult to guarantee compact support of the entire lower surface on the base. Due to these considerations, the area of one slab of a continuous prefabricated pavement usually is within 15-25 m^2. However, cases are known of laying reinforced concrete, pre-stressed slabs with much larger dimensions: 10.0 x 3.74 and 12.5 x 3.74 m [33].

Along with large slabs, slabs of medium and even small dimensions have been widely used. So, when constructing gauge roads, the width of one track, and consequently, the width of the slab is assumed to be equal to 1.0 m. The width of the slabs of such pavements is uaually assumed to be equal to 2.0-4.0 m. Slabs of small dimensions in the plane (in the order of 0.20 x 0.20 m, 0.50 x 0.50 m, 0.75 x 0.75 m) and of small thickness (6-10 cm) are used for covering sidewalks and park roads.

The designs of prefabricated pavements provide for different methods of joining the contiguous slabs and installation of joints between them. It is necessary to distinguish between two principal groups of different designs of joints and seams. The independent work of each slab is provided for separately in the designs of the first group under the effect of a moving load. The transfer of a load from one slab to another is absent.

Transfer of the load from one (loaded) slab to a contiguous one is provided for in the construction of the second group. For this purpose, welded, threaded and other types of connections are installed. Slabs having joints of such a type operate under better conditions: their bearing capacity as well as their resistance to the effect of dyhamic loads are improved.

In all the designs of prefabricated pavements, the seams are made with special materials preventing penetration of the surface moisture into the base. The designs of the joint units between the slabs of prefabricated-sectional pavements must provide the possibility of immediate disassembly and subsequent restoration of the pavement. On temporary roads, the joints are usually not completed.

In the designs of slabs for prefabricated and prefabricated-sectional pavements, it is necessary to provide for installations for a clamping and lifting. In a series of cases, these installations are made in the form of special mechanical loops on the front surface of the slabs. After laying the slabs, these loops are cut off. The lifting of the slabs with the aid of a vacuum-fork lift rack is more complete, which does not require special equipment in the designs of the slabs.

Different materials are used to make the slabs. The selection of the materials in each partial case is determined by the designation of the prefabricated design, the planned loads, the designated technology of the installation work and economic considerations. For the most part, reinforced concrete and concrete slabs are used for constructing the pavements of main highways, city streets, squares, aeroports and roads of special designation for heavy traffic, and also for pavements of temporary roads with a relatively long period of use. In some cases they use slabs of lithium slag, silicate-concrete, bituminous-mineral and asphalt concrete. For pavements of temporary roads with a short period of service they sometimes use inventory assemblies of metallic prefabricated-sectional pavements, wooden boards and synthetic materials as well as fabric and rubber.

The selection of the materials for slabs of different designation is made taking into account the special features of their design and the character of the stresses emerging in the process of installation, exploitation and disassembly.

Reinforced concrete resists the tensile forces and compressive forces well which emerge with deflection. Thus, reinforced concrete slabs may be used for all types of prefabricated pavements. In the practice of construction, it is usually used for making large-dimensioned slabs of highway pavements and prefabricated elements of bases under rails and pavements for street car tracks. Slabs made of prestressed reinforced concrete have been widely used.

Concrete of the higher brands (300-500) withstands well the stresses emerging from the load of moving automobiles and in the process of installation (with small dimensions of the prefabricated elements). Concrete slabs of small dimensions are used for the installation of pavements as well as for reinforcing the shoulders

and the inclines of the ground. Silicate and lithium slag slabs are used for these purposes.

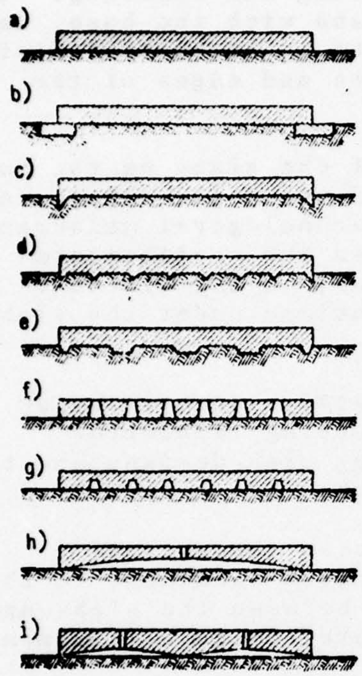


Fig. 3.--Different forms of the contour of the support surface of slabs:

a) smooth
b) smooth with foundations in the seams;
c) smooth with perimeter skirting
d) fine-ribbed
e) caisson
f) with through vertical apertures;
g) with deep recesses
h) dome-shaped
i) roof shaped

It is necessary to separate out the cases of using asphalt-concrete and bitiminous-mineral slabs.

Asphalt-concrete slabs are made with small dimensions for installing pavements in hindered situations. Works in the use of asphalt-concrete slabs are still in a stage of study.

Bituminous-mineral slabs are preferably made with medium dimensions: 1.75x3.00 m and 2.0x3.0 m with a thickness of 14-20 cm and are used for the construction of bases under improved pavements. More dangerous stresses emerge in bituminous slabs in the periods of their loading and unloading (during transfer) and with installation. Since the strength and resistance of bituminous-mineral slabs is increased with dropping temperature, then for the construction of road toppings from these slabs it is necessary to provide for maximum use of the winter period.

A layer of rubble, gravel, sand and also dirt reinforced with different binders is used as the base under the reinforced pavements.

The stability and the efficiency of reinforced pavements to a considerable degree depend on the properties of the underlying layer (base) and on the providing of tight support (contact) of each slab with the base. This dependence is especially great in slabs of the rigid type, poorly absorbing the tensile forces at bend (concrete and poorly reinforced ones).

In monolithic constructions, the pavement materials (different asphalt-concrete and concrete mixtures, rubble etc) are laid down on the base in loose form. In packing down these materials, they provide for filling in all unevennesses of the base and tight contact between the pavement and the pase at any point.

In the case of insufficient compactness and stability of the base under the effect of automobile traffic, there is a decline in the evenness of the prefabricated pavements. In individual cases, this may take place even without significant damage to the slabs, because of their non-uniform settling and shifting. In the case of unsatisfactory contact of the slabs with the base, we also observe gradual loosening, which leads to an accumulation of uneven settlings of the base under the corners and edges of the slabs.

In order to guarantee compact support of the slabs on the base, in a series of designs, complex contouring of their lower base was undertaken (Fig. 3). In addition, special technological measures were worked out to improve the contact between the prefabricated pavements and the base: vibration of the slabs, laying discrete materials on the base, forcing of cement solutions under the slabs, etc.

At the present time, scientific-investigative work is being continued in the area of planning and constructing reinforced pavements and bases, directed toward improving slab designs and toward working out new methods for their installation.

The main directions in these studies are in the area of constructing and enlarging the used prefabricated elements; in the area of technology, providing better contact between the slabs and the base and increasing the evenness of the prefabricated pavements.

It can be assumed that one of the best constructive solutions in the construction of reinforced pavements on highways of higher categories will be the use of large-dimensioned slabs of a more simple rectangular form. The best solution in technology up to now has been vibro-setting of the slabs on bases made of discrete materials, reinforced with different binders.

2. Prefabricated Cement-Concrete Pavements

Cement-concrete (concrete) slabs are used for constructing highway pavements, sidewalks, pedestrian paths, and also for reinforcing the shoulders and inclinations of earthen road beds. The dimensions of the cement-concrete slabs to a considerable degree are limited by its insufficient bending strength.

The absolute values of elongation stresses, emerging in concrete under the effect of a moving load, and also from gravity in the process of the installation work, with uniform thickness of the slab, essentially depend on its dimensions in the plane. They increase with an increase in the length and width of the slab. The increase in the dimensions of concrete slabs in the plane is connected with the necessity of greatly increasing their thickness, which in the majority of cases is not economical. Thus, from cement-concrete it is customary to make slabs of small dimensions with an area up to 1.0 m^2, in rare cases up to 3-4 m^2 or somewhat larger.

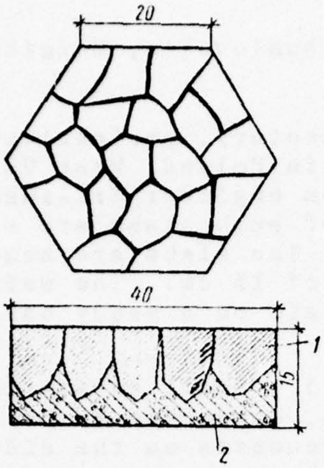


Fig. 4.--Concrete road slabs with a design by the engineer Trilinsk:
1-Stones of durable variety.
2-Concrete

Slabs of small dimensions made of finely granulated concrete are widely used for the construction of sidewalk covers in many foreign countries: Italy, Poland, GDR, Czechoslovakia, Federal Republic of Germany, and so on. In the USSR, sidewalks and park roads are covered with concrete slabs. Detailed information concerning the design of prefabricated sidewalk coverings is given in Chapter VI.

Concrete slabs are used rather infrequently for the construction of highway pavements. This can be explained for the following reasons:

great elongation of the joints occurring per unit of pavement area, which makes their evenness much worse;

an increase of the danger of water penetration through the joints into the base;

the difficulty of mechanizing the work in laying the slabs, an increase in the extent of manual labor and total man hours per job of the entire constructional process in laying the pavement.

But together with the disadvantages of prefabricated pavements made of concrete slabs with small dimensions, there is a series of positive characteristics:

small dimensions of the slabs in the plane guarantee good contact of them with the base;

with small dimensions of the slabs, frequently laid down without the construction of joint connections, dismantling of the pavement and its restoration with repeated use of the same slabs is greatly simplified;

small dimensions and correspondingly low weight of the slabs make it easier to carry out the work under difficult conditions (tunnels, narrow passageways, etc);

from slabs of small dimensions it is convenient to construct pavements on travelled parts of non-standard width (at bus stops, widenings on turns, on squares and courtyards with irregular shape etc).

These positive characteristics of prefabricated pavements made from concrete slabs of small dimensions facilitate their propagation

of use in many countries of the world (Czechoslovakia, Belgium, Holland, France and the USA, etc.).

In the twenties and thirties of this century, prefabricated pavements made of concrete slabs were used in Poland, West Ukraine and Western White Russia by the construction engineer Trilinsk (Fig. 4) Individual sections of the pavements made of such slabs are still in good conditions after twenty years of use. The slabs are hexagonal in shape with a side of 20 cm, a thickness of 15 cm. The weight of the slabs is 35-37 kg. The slabs were laid on a sandy base.

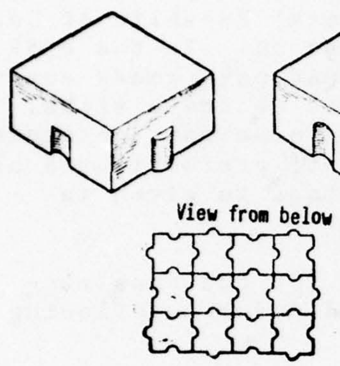


Fig. 5.--Small square concrete slabs, connected by projections and recesses on the side grains.

Since 1926, concrete block pavements have been used in Belgium, Holland and France. About 300,000 m^2 of road pavement from square concrete blocks having a dimension of 50x50x12 cm were constructed in Czechoslovakia in 1934-35. In these blocks, as well as in the hexahedrons of Trilinsk, the upper, travelled part of the blocks was reinforced due to its saturation with stones of the stable variety. Such a saturation was achieved by the fact that in the process of manufacturing the slabs, a layer of stone was laid on the bottom of the concrete form with its facial surface down with subsequent pouring of the forms with a concrete mixture.

In Poland, in 1934, some parts of roads were constructed with concrete blocks having a dimension of 50x20x20 cm. The blocks were made triple-layered: the upper layer had ratio of cement to sand of 1:2, the middle layer 1:3, the lower layer 1:5. Granite or limestone rubble was used in the concrete.

In Poland and in Czechoslovakia, rather wide use was made of prefabricated pavements made of cement blocks with dimensions 33x33 cm. The height of the blocks was changed in the limits from 8 to 20 cm depending on the character of the traffic. On the side grains of the blocks there were twin or single ridges (projections) and, corresponding to them, grooves to provide better stability of the blocks subjected to traffic (Fig. 5). The blocks were made by the method of pressing with hydraulic presses under a pressure of 200 atm with simultaneous vibrating. Laying of the blocks was accomplished along a crushed stone base with a thickness of 10 cm.

For the past few years, prefabricated concrete pavements have also been widely used in England, the USA and on the African continent. So, in the USA, concrete blocks are used with dimensions 30x30x10 cm in places where it is difficult or impossible to work with road-building machines; on narrow passages, in tunnels, etc.

At the present time, in some cities of Belgium and Holland, special plants are being organized for making concrete blocks of rectangular shape. Higher requirements are made on the concrete of such blocks: minimum strength of the cubes 7x7x7 cm on compression must amount to not less than 750 kg/cm^2, the porosity must not be less than 4%. The blocks are made either eith smooth, vertical grains, calculating the independent work of each of them, or with chamfered or curved grains, guaranteeing joint work of the adjacent blocks. The dimensions of the blocks is usually 16x16x14 cm. Sometimes they use blocks 20.3x25 cm with a height of 7-14 cm.

Concrete blocks are widely used in the Federal Republic of Germany. There are sections of pavement made of concrete blocks which, with a traffic intensity of 30,000 vehicles per day last 20 years and more and remain in good condition.

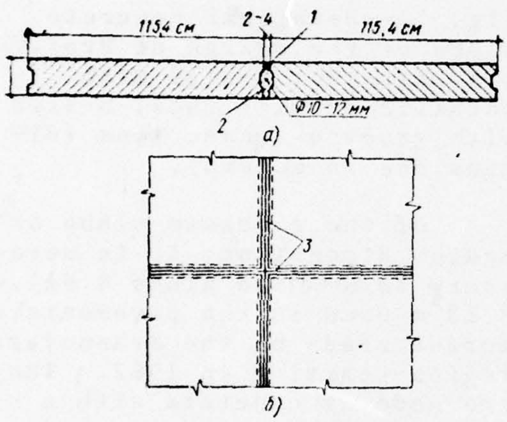


Fig. 6.--Square, concrete slabs connected with dowels of a reinforced solution: a-cross section; b-plane; 1-Cement; 2-Cement solution; 3-reinforced bars.

In Hungary they use prefabricated concrete pavements from slabs of the dimension 115.4x115.4x18 cm (concrete brand 500). Crushed stone with a dimension up to 40 mm and large-grained sand are used in the cement mixture. The water-cement ratio of the concrete mixture is 0.45-0.48. The slabs are made on vibrating tables and then steamed out at a temperature of 50-80°. The connection of the slabs with each other is accomplished with dowels from a reinforced solution (Fig. 6).

In the Soviet Union, designs of concrete slabs of small dimensions are known, proposed by Prof. I.A. Kirienko in 1928. They are hexagonal slabs with a thickness of 15 cm with a dimension of the side of 30 cm. The weight of one slab amounts to 77 kg. In the pavement, adjacent slabs are connected to each other by metal rods, passing on the inside. Apart from the hexahedrons, semibeams are made for laying along the edge of the pavement creating a straight-line shoulder of the travelled part. The clearances in the junctions are 5-10 mm. Experimental sections with a pavement from slabs of the designer I.A. Kirienko were first constructed in Kiev, and in 1939 in Moscow at the approach to the B. Krasnoxolmsk bridge and on the embankment of the Yauz River.

In 1948, Prof. I.A. Kirienko proposed a new construction for slabs (Fig. 7) of less weight. The form of the slab in the plane was kept hexagonal. Unlike the new construction, the new slab has a grooved connection which made it possible to better transmit the force from the temporary load onto the neighboring slab. The weight of one block equals 34 kg, which makes it possible to lay it by hand. It is recommended to lay the slabs on the sandy, levelled layer with a thickness of 3-5 cm. The author foresees the possibility of increasing the cohesion coefficient of the pavement along with the automobile tires by means of the channeling of driven over surface of the slabs, and also improving their external appearance by using a kind of crushed stone in the concrete composition such that they have a different color. Such designs are used to a limited extent in contemporary road construction. In 1956, slabs of the design of Prof. Kirienko were used for constructing a cover on the square at the Sofiisk cathedral in Kiev.

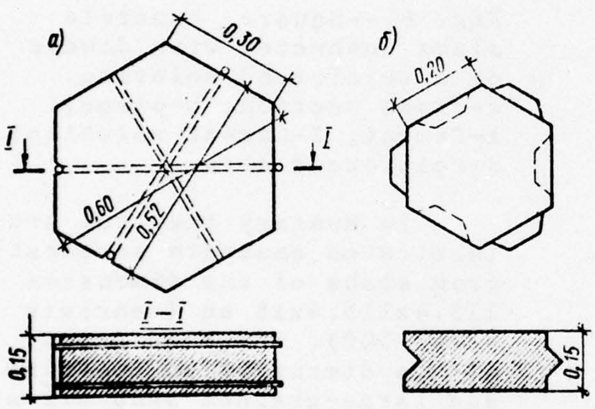


Fig. 7.--Hexagonal concrete slabs of the design of Prof. I.A. Kirenko: a-Slab with metallic drawing rods; b-Slab with grooved connections (dimensions in meters).

Of the concrete slabs of medium dimensions, it is necessary to note the slabs 0.9x1.0x 0.18 m used in the pavements of forest roads of the Krasnoyarsk region starting in 1962. They are made of concrete with a limit strength at compression of 300 kg/cm^2 and a bending stress of 45 kg/cm^2. Pavement made of these slabs stay in good condition after several years of use.

V.N. Pogorzhelskii proposed using round concrete slabs of variable thickness for high prefabricated pavements, i.e. it is maximum at the edges and gradually is decreased toward the center, where its cross section is reinforced with local concentric reinforcements (for equal strength of the slab) [7]. The side grains of the slab are tapered to the base and an oblique channeling is provided on them. In the opinion of the author, these measures must facilitate the transmission of forces of the moving load from one slab to another through the material, filling up the spaces between them. However, this does not correspond to actual distribution of forces, since the proposed design of the junction cannot transmit either intersecting forces nor the bending moment from one slab to another.

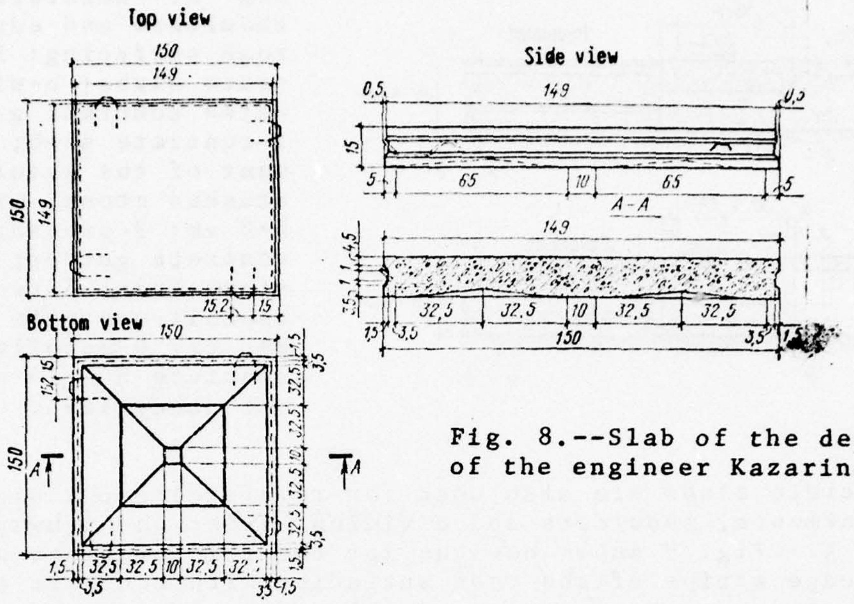


Fig. 8.--Slab of the design of the engineer Kazarinov.

Channeling of the lower surface is also provided for in the designs of V.N. Pogorzhelsk which, with regard to the variable thickness, improves the joining of the slab to the base. The compactness of slab joining guarantees their work in conditions close to the calculated ones, owing to which they can be made with a diameter up to 1.5 m without fittings. Such a design in the plane is more stable and economical as to the consumption of material. The slabs are laid in the pavement with a shift of one row relative to the other on half the diameter. It is recommended to fill the formed profiled intervals between the slabs with cast asphalt or some other kind of elastic-viscous-plastic material which is more deformable than cement concrete.

The presence of these interspaces is a significant defect of prefabricated pavements made of round slabs. The work required greatly increases the cost of the pavement as a whole. The use of bituminous-mineral materials in large volumes complicates the organizational and technological carrying out of the work.

The idea of a contoured support of the slabs with subsequent providing of support over the entire area by means of the injection of a cement solution under them was accomplished in 1951 according to a proposal of the engineer Kazarinov [37]. Such slabs were used for the construction of the Moscow-Gorkii road on the Moscow-Noginsk section. They had a square shape in the plane (150x150 cm) with a thickness of 15 cm (Fig. 8) were reinforced only with an installation fitting. These slabs have not been widely used due to the complexity of making and laying them.

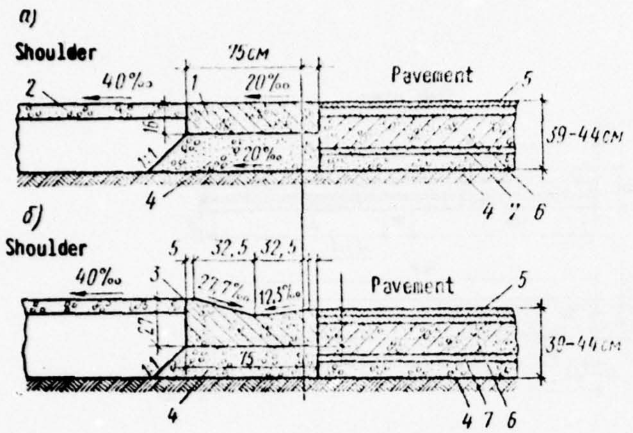
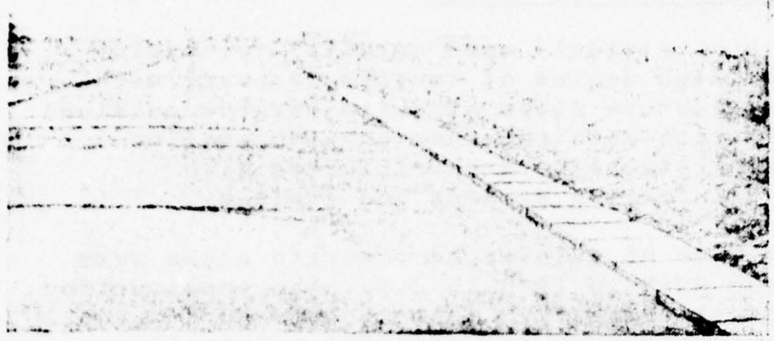


Fig. 9.--Reinforcement of shoulders and edges of the road surfacing: 1-with concrete slabs; b-with prefabricated concrete gutters; 1-concrete slab; 2-reinforcement of the shoulder with crushed stone, with a layer h=8 cm; 3-prefabricated concrete gutter; 4-crushed stone base; 5-two-layered asphalt-concrete pavement h=8 cm; 6-monolithic cement-concrete h = 18 cm; 7-smoothed out sandy layer h = 3-5 cm.

Concrete slabs are also used for reinforcing the slopes of the embankments, shoulders and dividing strips on highways of category I. Fig. 9 shows designs for the reinforcement of shoulders and the edge strips of the road surfacing with concrete slabs and prefabricated concrete gutters, developed in the planning of the Alma-Ata--Novoiliisk road of category I.

The passing lane on this road was planned in the form of two strips of 7.5 m with a dividing strip having a width of 5.0 m. The road surfacing is an asphalt-concrete pavement on a cement-concrete base. Each strip of the travelled part is bordered on both sides by two strips having a width of 0.75 m with a pavement of concrete slabs. The dimensions of the slabs are 1.00x0.75x0.16 m and 1.50x0.75x0.16 m. Longer slabs are constructively reinforced with rods Ø6 mm to prevent the appearance of cracks in the installation process. Prefabricated concrete gutters are placed on individual parts (with a large runoff of surface water). The dimensions of the elements of the prefabricated gutter in the plane are 1.00x0.75 m. The thickness varies from 0.27 to 0.18 to 0.22 m. The slabs and the gutters are laid down on the crushed stone base with a thickness of 15-18 cm.

The design of the slab provides for special eyelets for them to be picked up by a crane. Three variations have been worked out for their installation. According to the first variation, the eyelet is projecting from the front surface of the slab, and after laying, they are cut off by an autogenous welder.



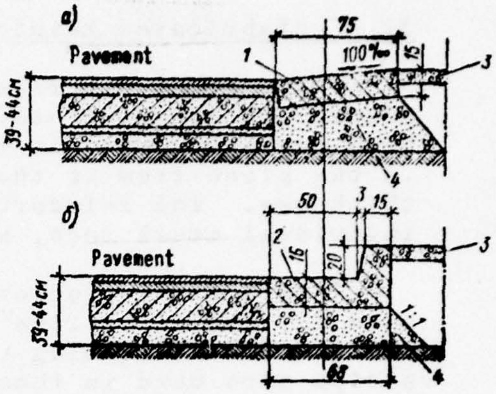


Fig. 10.--Concrete slabs on the shoulders of the road before installation of the pavement.

Fig. 11.--Reinforcement of the median strip edges: a-with rectangular concrete slabs; b-with concrete curb slabs of Γ-shaped profile; 1-rectangular concrete slab; 2-curb concrete slab; 3-median strip, reinforced with crushed stone; 4-crushed stone base.

According to the second, after laying, the evelet is folded down into a speically made recess. According to the third, they remain at the side and are covered over by a layer of crushed stone covering the remaining part of the shoulder. The slabs are laid on the shoulder until construction of the pavement in order to use them in the process of constructing the pavement in the capacity of supports. (Fig. 10).

Reinforcement of the edges of the median strip is carried out with the same slabs (1.00 x 0.75 x 0.16 m) as in reinforcing the shoulder. The difference was only in the transverse inclination: the slabs on the shoulders were laid down with an inclination of 20%, on the median strip edges with an inclination of 100%. According to another variation, the edge of the median strip is reinforced with a special concrete curb slab of a complex contous (Fig. 11).

In some cases, concrete slabs with dimensions 0.50x0.50x0.12 m with a grooved surface were used to reinforce the strip along monolithic pavements. The small dimensions of the slabs facilitate their laying. The grooved surface makes the movement of automobiles more difficult along the reinforced strip and forces the driver to reduce his speed when he moves onto it.

Prefabricated concrete designs of curb strips along monolithic pavements on highways of a high technical category, such as described earlier, are also used abroad.

3. Prefabricated Reinforced Concrete Pavements

Reinforced concrete is a more widely used material for making prefabricated pavements. The high degree of tensile strength with bend makes it possible to manufacture slabs of quite large dimensions in the plane from it than concrete with the same or even smaller thickness. The reinforced concrete slabs are reinforced with individual steel rods, with reinforcing screens and casings.

Prefabricated pavements made of reinforced concrete slabs were used for the first time in the USSR in 1940-1943 for the construction of takeoff and landing strips at airports. Rectangular and hexagonal strips were used in these coverings with an area of 1.0-2.5 m^2.

Prefabricated reinforced concrete constructions were widely used in the construction of approach roads and temporary roads (continuous and gage) at the time of constructing the Kuibishevsk and Volgograd GES. A great amount of work in studying the design and technology of making and constructing reinforced concrete prefabricated-sectional pavements was carried out by doctoral candidate A.V. Yakovlev (see Chapter VII).

Construction of experimental sections of reinforced pavements from reinforced concrete slabs in the period of 1954-1955 was accomplished on a series of roads in our country. In September-October 1954 on the Rostov-Ordzhonikidze road (in the region of the city of Kropotkin) they constructed prefabricated pavements with a length of 342 m from slabs with a dimension of 3.0x1.75x0.16 m, reinforced in two layers with roads having a diameter of 10 mm.

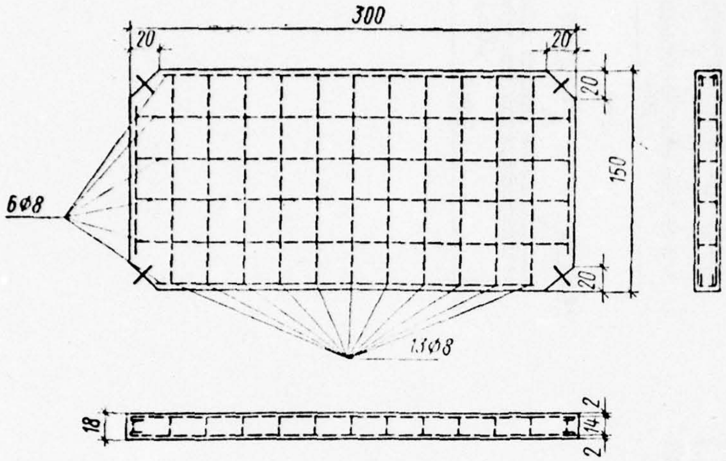
A section of reinforced pavement with a length of 3.6 km made of reinforced concrete slabs was built in the spring of 1955 in the city of Parlodar Kazaxsk SSSR. Here they used rectangular slabs with a dimension of 3x1.5x0.18 m (Fig. 12) having chamfers on the corners.

With the reconstruction of the Moscow-Gorkii main highway, at the bypass of the city of Noginsk in 1955, the construction of an experimental part was accomplished with a prefabricated pavement made of reinforced concrete slabs with a dimension of 3.5x2.0x0.20 m, laid with the long sides transverse to the travelled part. A total of 600 slabs were laid. The slabs were connected to each other by welds in the corners of the looped outlets of the fittings.

In the same period, prefabricated reinforced concrete pavements were used in the city of Novosibirsk, on individual constructions of the Urals and the Donbass. This time also saw the beginning of an experimental construction of prefabricated pavements from reinforced concrete slabs on city streets.

So, in 1951 on B. Serpuxov street in the city of Moscow they built experimental sections of prefabricated pavements made of square and hexagonal reinforced concrete slabs with a general area of about 1000 m^2. For the construction of prefabricated pavements on the streets of the city of Moscow, the planning institute "mosinzhproekt"

worked out a design of reinforced concrete slabs having a square shape (1.54x1.54x0.16 m), a rectangular shape (1.75x1.50x0.16 m) and a hexagonal shape with a 1.16 m side (Fig. 13) and a thickness of 16 cm.



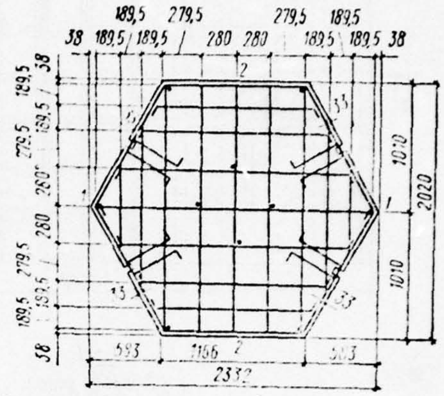


Fig. 12.--Design of reinforced concrete slabs for a road pavement in the area of the city of Pavlodar.

Fig. 13.--Hexagonal, reinforced concrete slab of a design of the "Mosinzhprojekt" institute.

In the period of 1960-1962, prefabricated pavements were constructed from hexagonal, reinforced concrete slabs according to the design of "Mosinzhproekt" in the inhabited region of Xoroshevo-Mnevniki and on B. Cherkizovski street in Moscow. On one of the sections of the Xoroshevo-Mnevniki in 1960 they constructed a prefabricated pavement of ribbed, vibration-rolled slabs (design of the "Mosinzhproekt" institute with a dimension 2.5x3.5 m with a general area of about 700 m^2), Fig. 14.

Prefabricated pavements were used on temporary access roads with the assimilation of new developed regions in the city of Moscow (on the south-west, in Novii Chermushkax and Peschanii streets, and also for the construction of the Central Stadium named for V.I. Lenin).

In the last few years, prefabricated reinforced concrete roads were constructed in other cities of our country. In 1962, experimental sections of prefabricated pavements with a general area of about 30 thousand m^2 were constructed in the cities of Odessa, L'vov, Kovel, Xmel'nitsk and others. In 1963, in the cities of the Ukraine, they had already built more than 120 thousand square meters of prefabricated, reinforced concrete pavements.

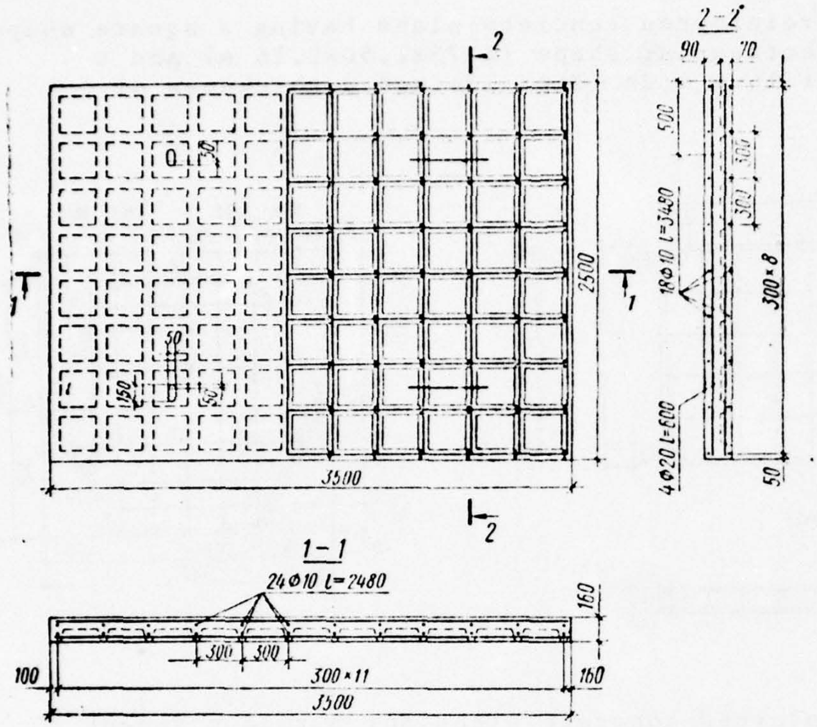


Fig. 14.--Vibration-rolled, ribbed slab of the "Mosinzhproekt" design.

According to the program of the Ministry of Communal services, the department for the organization and mechanization of road-construction work of the Kiev automobile-road institute under the direction of Prof. V.A. Rudenko worked out a design of reinforced concrete slabs for the pavements of city streets and sidewalks of the following types: rectangular with a flat base (Fig. 15), rectangular with a contoured skirting in the base and with a fine-ribbed base (Fig. 16) on longitudinal foundations (Fig. 17).

All of the slab designs basically have small dimensions: 1.5x1.75; 1.5x3.0; 1.75x3.0 and 2.75x3.0 m with a thickness from 14 to 20 cm. They are recommended for experimental construction.

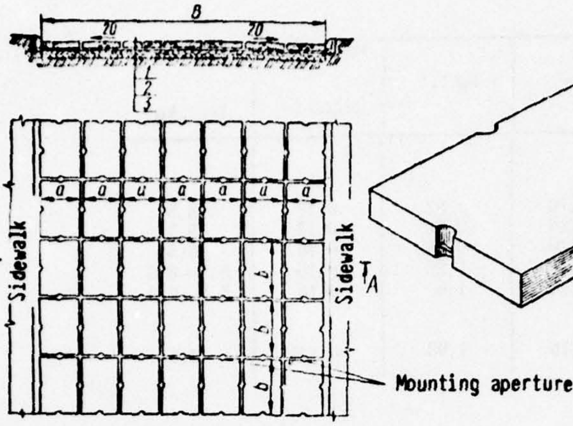


Fig. 15.--Rectangular slabs with a flat base:
1-concrete slabs with a flat base; 2-layer of sand or stone residue; 3-base with thickness h

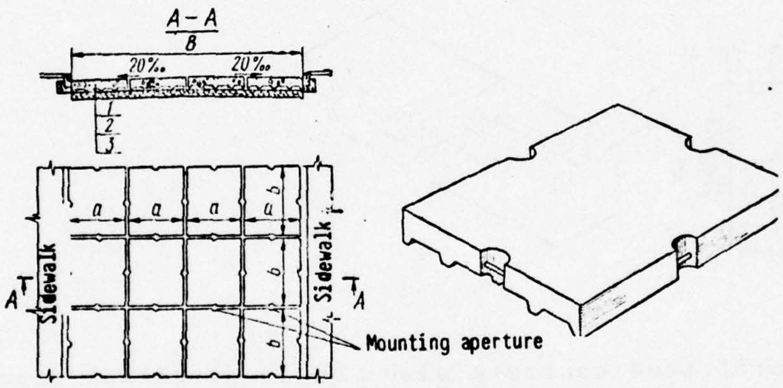


Fig. 16.--Rectangular slabs with a ribbed base:
1-concrete ribbed slabs; 2-layer of sand or stone residue; 3-base with a thickness h.

Theoretical and experimental studies, connected with the question of deciding the practicality of using prefabricated road pavements, have been carried out in the past few years in the Ural NII.

The K.D. Pamfilov academy of community services developed a design of so-called jointed slabs for road pavements (author doctoral science candidate P. P. Kovalenko), the basic data of which are shown in Table 1.

Table 1

Slab make	Dimensions,m	Weight,t	Material expenditure per 1 m²	
			Concrete	Steel,kg
Jointed without interstices				
СШ 2×1,5	1,5×3,0×0,16	1,82	0,17	8,5
СШ 3×1,5	1,5×4,5×0,16	2,78	0,17	8,5
СШ 2	1,0×2,0×0,16	0,80	0,16	6,5
СШ 3	1,0×3,0×0,16	1,20	0,16	5,5--6,5
СШ 4	1,0×4,0×0,16	1,6	0,16	5,5--6,5
Jointed with interstices				
SOP 2x1.5	1,5×3,0×0,16	1,93	0,155	8,5

Note:The concrete brand of all slabs is 300.

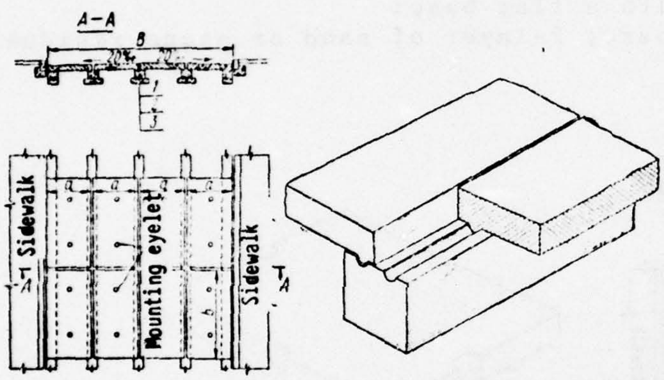


Fig. 17.--Reinforced concrete slabs on longitudinal foundations: 1-Reinforced concrete slab; 2-Reinforced concrete foundation; 3-base under the foundation with thickness h.

The special feature of these slabs (Fig. 18) is the rustic masonry of their upper and lower surface, owing to which the slab is as if divided up into a series of individual slabs with a dimension 1.0x1.0 or 1.5x1.5 m, divided up by pseudo-junctions. In the process of using the pavement, developing cracks coincide with these junctions and the slab is broken up into several fine units, hinged to each other with the aid of fittings.

The main disadvantage of pavements made of jointed slabs is moisture getting into the base through the surface through the cracks in the rustic masonry and corrosion of the connection fittings in the pseudo-junctions. In addition, with the extended effect of automobile load, we observe puncturing of the concrete around the connecting rods.

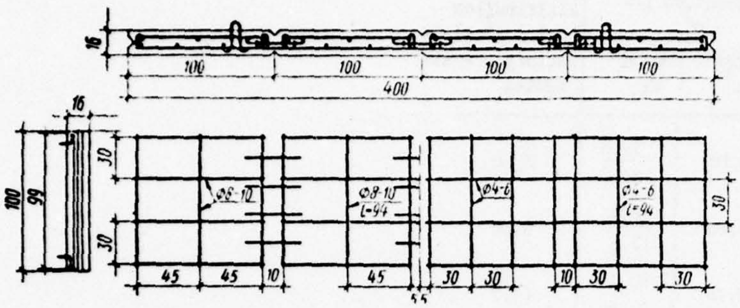


Fig. 18.--Articulated road reinforced concrete slabs according to the design of UralNII AKX in the name of K.D. Pamfilov.

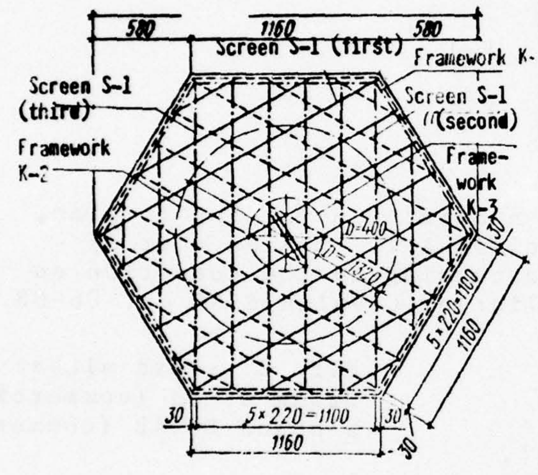


Fig. 19.--Hexagonal road slabs of the brand DSSH-2.

According to the specific expenditure of concrete and fittings, articulated joints have no advantage over other types of prefabricated pavements. The author's basic reason for using the given design of prefabricated slabs is an increase in labor productivity when they are made and laid, compared with an equal quantity of individual slabs of small dimension.

At the present time, the department of city designing and building of the Chelybinsk polytechnical institute is working on improving the articulated slabs. Sections of prefabricated pavements made of articulated slabs were constructed in Sverdlovsk, Berezovk, N. Tagil and other cities. Typical designs of prefabricated reinforced concrete road slabs for city streets and roads were worked out according to the plan of typical projection of the State construction office SSSR by the planning institute "Mosinzhproekt" at the GlavAPU Mosgorispolkoma. The basic characteristics of the slabs are shown in Table 2.

The road hexagonal slab of brand DSSH-2 (Fig. 19) is reinforced with screens and steel frameworks Ø 6 mm class A-III and cold-drawn wires with a diameter of 4 mm of class V-I. The dimension of one side of a slab is 116 cm, the thickness is 18 cm.

Table 2

Group	Make	Brief characteristics of slabs	Dimensions, cm a	b	c	Wt. t	Expenditure per 1 m² Concrete m³	Metal kg	Distribution cost 1 m² slabs factory prepaid rubles
I	ДСП-2	Hexagonal	116	201	18	1,58	0,18	$\frac{8,48}{12,10}$	6,30
	ДСП-1Б	Rectangular with conventional fittings	150	170	18	1,18	0,18	$\frac{12,4}{17,5}$	6,88
I	ДСП-4	Same	300	350	18	4,7	0,18	$\frac{10,4}{14,8}$	6,77
	ДСП-4-10	Same	300	350	18	4,7	0,18	$\frac{8,85}{12,6}$	6,43
	ДВП-5Б	Ribbed, vibration-rolled	320	350	18	3,5	0,125	$\frac{10,2}{14,5}$	6,43
	ДВП-7Б	Same	320	350	16	3,28	0,117	$\frac{14,25}{20,4}$	6,25

Note: 1. Expenditure of metal: In the numerator according to plan, in the denominator--relative to steel class A-I. 2. The cost of construction calculated in the prices according to the condition on 1 January 1966 according to the price list of Gosplan SSSR No. 06-08.

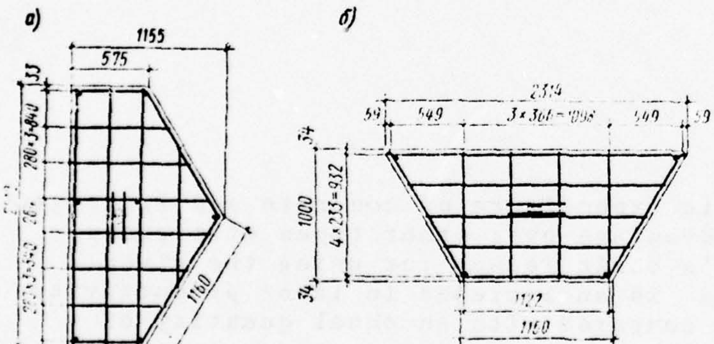


Fig. 2.--Road slabs: a-Brand DS-55 (commercial); b-brand DS-4B (commercial).

The basic advantage of hexagonal slabs is the possibility of laying them in the pavement in any direction. Moreover, the efficiency of the slabs in all directions is the same. In the corners

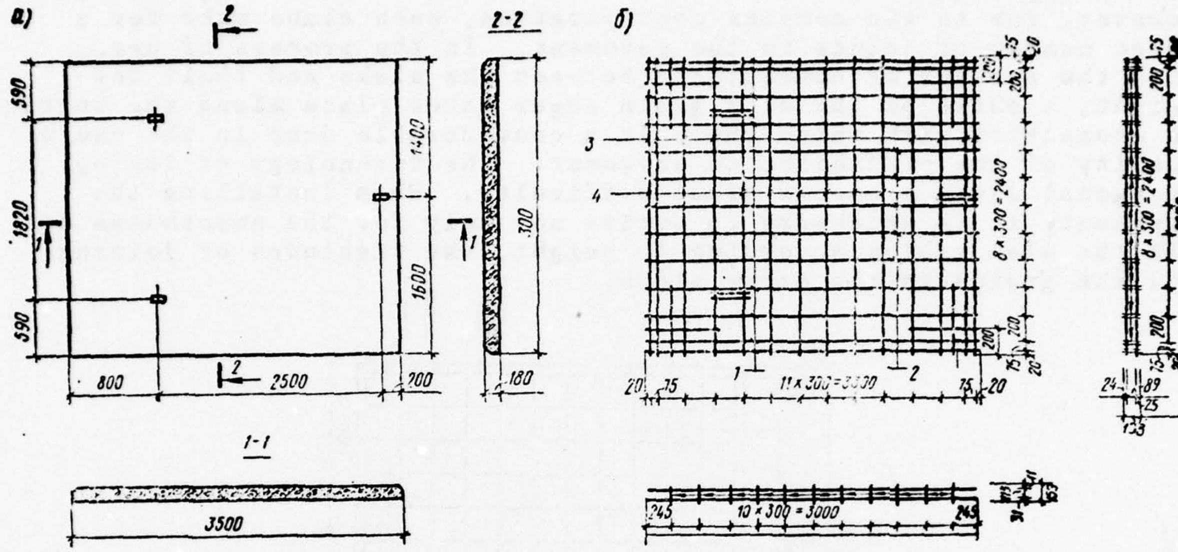


Fig. 21.--Reinforced concrete slab for city thoroughfares: a-lining diagram; b-diagram of the fitting; 1-framework K-1 (8 pieces); 2-framework K-2 (5 pieces); 3-framework K-3 (8 pieces); 4-framework K-4 (6 pieces).

of hexagonal slabs, the danger of the appearance of tensile stresses in the upper zone of the concrete is less than in rectangular ones. However, due to the complex configuration, such slabs make for a large number of joints in the pavement. In the process of use, with the absence of connections between the slabs and their low weight, a shift of the side grain edges takes place along the vertical, in connection with which there is a considerable drop in the useful quality of the prefabricated pavement. The technology of laying hexagonal slabs presents great difficulty. When installing the pavement, it is necessary to strive not only for the smoothness of all the slab grains according to height, but tightness of joining all the grains to the other slabs.

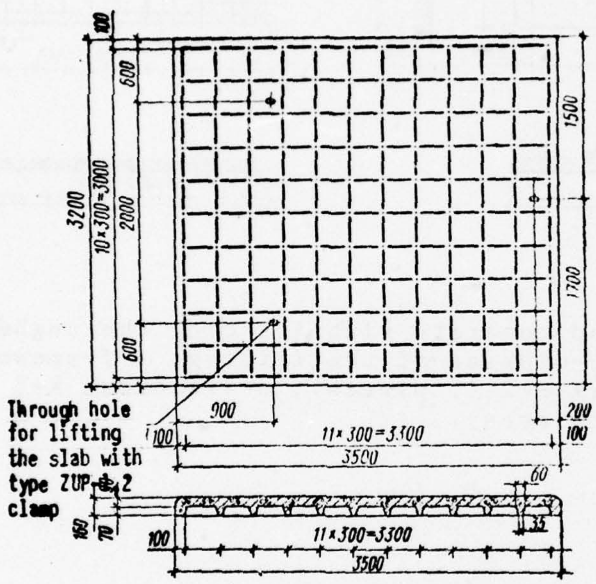


Fig. 2.--Vibration-rolled, ribbed slab, brand DVP-7b

As a supplement to slabs DSSH-2, provision was made for manufacturing a semi-slab brand DS-5B (Fig. 20,a) and DS-4B (Fig. 20,b).

Road slabs of the brands DSP-1B, DSP-4 and DSP-4-10 (Fig. 21) have corresponding dimensions in the plane 1.75x1.50 and 3.5x3.0 m. They are reinforced with frameworks from fittings having diameters 5 mm (class B-1), 6; 9 add 10 mm (class A-III). The slabs of brand DSP-4 and DSP-4-10 have the same dimensions and differ from each other by the different degree of reinforcement (correspondingly, 10 kg per 1 m^2 of slab and 8.85 kg per 1 m^2). The thickness of all the slabs is 18 cm. In addition to being laid on city thoroughfares, slabs of the brand DSP-1B may be used for temporary road constructions.

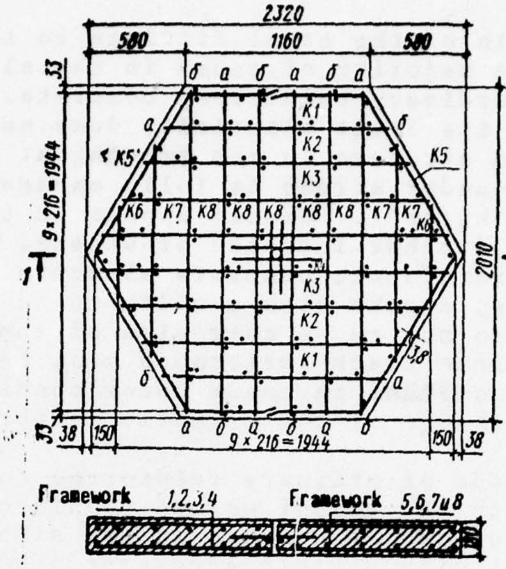


Fig. 23.--Road hexagonal slab with with a rigid reinforcing framework.

The typical designs of road slabs of the brands DVP-5B and DVP-7B also have a rectangular shape. The slabs are made with the method of rolling on a belt of a rolling mill BSP-6 of the design of H. Ya. Kozlov. The vibration-rolled slab of the brand DVP-5B has dimensions 3.2x3.5x0.18 and is reinforced with frameworks of fittings with a diameter of 6 and 11 mm class A-III and with a wire of the diameter 5 mm class V-I. The slab of brand DVP-7B (Fig. 22) with the same dimensions in the plane has a smaller thickness 0.16 mm and is reinforced with similar frameworks of fittings of the same class with a diameter of 8 and 12 mm.

The concrete brand for all road slabs of typical design is 400; its frost stability is not less than 200 cycles. All the slabs are laid without a mutual connection with mandatory vibration setting.

The standard load for all slabs is taken from class N-30 with a calculated load on the wheel 6.0x1.2=7.2 t. The slabs are laid on a sandy underlayer, the upper part of which is reinforced with cement at a depth of 10 cm (130 kg per 1 m^3 of sand).

At the present time, the production of reinforced concrete slabs is being assimilated in Moscow with the method of high-power vibration rolling. In such slabs (Fig. 23) the solid reinforced framework is formed of steel rods with a diameter of 10 mm. The slab is lifted with a clamp let down through an opening in the center, and is reinforced along the edges with reinforced bracings.

4. Prefabricated Pavements from Prestressed Reinforced Concrete

The high strength of the steel fittings to tensile stresses is not fully used in the majority of cases in the slabs of prefabricated pavements made from ordinary reinforced concrete. Concrete works poorly under stress; its limit elasticity does not exceed 0.1-0.2 mm/m. The elongation stresses in the fitting at the moment when the work of the concrete under stress is fully exhausted, turn out to be small (about 200-400 kg/cm^2). Cracks appear in the stretched zone of the concrete with further increase of stress. According to existing standards in reinforced concrete elements of industrial and engineering buildings, cracks with a width up to 0.02 mm are permissible, ordinary they do not cause corrosion of the metal. However, requirements of complete crack-resistance must be placed on reinforced concrete slabs installed on roads under conditions of constant moisture and with a change of the climatic factors.

In road slabs made of ordinary reinforced concrete, crack formation is limited with the use of welded reinforcing frameworks or by the distribution of reinforcements in the slab. This makes it possible to use steel with a yield stress of 3500-4000 kg/cm^2. The use of stronger steels, which would make it possible to reduce the expenditure of reinforcements and their cost is not advisable because of the impossibility of discovering cracks. Using pre-stressing, it is possible to rationally use high-strength steel and to obtain crack-resistant, reinforced concrete slabs for road toppings.

Reinforced concrete elements in manufacture, even up to their loading with operational loads, are used in a stressed state. In those construction zones where tensile forces emerge in the period of operation, compressive stresses are created beforehand in the manufacturing process. They must be counterbalanced or even the elongation stresses of the operational loads must be exceeded. Thus, the elongation of the concrete the appearance of cracks which is connected with this is done away with or greatly postponed.

The basic advantages of prestressed pavements compared with surfaces made of ordinary reinforced concrete are as follows:

1) substantial reduction in the expenditure of reinforcements and of concrete thanks to the use of high strength materials and reduced thickness of the slabs;

2) a considerable increase (almost a full guarantee) of slab crack resistance;

3) increase of endurance (which is especially important for road slabs, operation under multiple repeated load);

4) some increase of frost resistance due to an increase in the density of the concrete under compression;

5) reduction of the transport expenditures in the course of construction due to reducing the weight of the slabs.

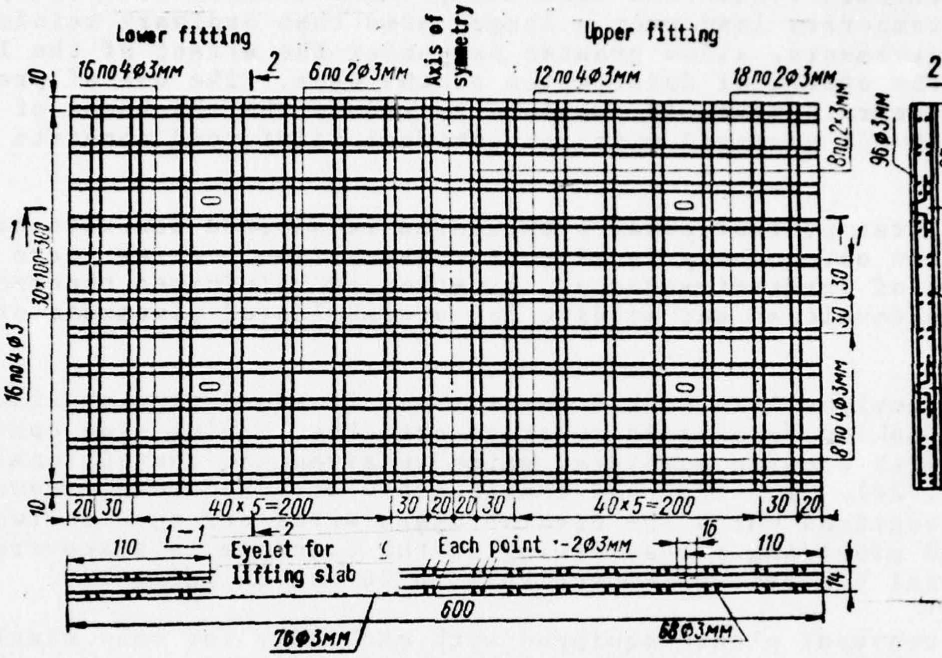


Fig. 24.--Airport slab P-ФX with double-axle, double-layered, stressed reinforcement.

Prestressed reinforced concrete pavements distribute the pressure from the temporary load over a larger area than ordinary reinforced concrete pavements, allow greater sag under the effect of the load or under the effect of deformation of the base. The use of prestressed concrete makes it possible to reduce the thickness of the pavement 25-40% compared with conventional reinforced concrete pavements.

The first prefabricated prestressed reinforced concrete pavements were used in our country in airport construction. A few years ago, some types of large-dimensioned, prestressed reinforced concrete slabs were developed and studied for prefabricated pavements of airports.

Slab designs were worked out for use in manufacturing slabs in plants making reinforced concrete articles, having side conveyers, equipped with winding machines, which received the conventional name P-IX (Fig. 24). The slab has continuouslv stressed reinforcements in two directions which are high-strength wires arranged in two layers and providing pre-stressing in the concrete in transverse and longitudinal directions respectively in 28 and 21 kg/cm^2.

For conveyor plants equipped with machinery for onlv single-axis (longitudinal) stressing of the reinforcements, they worked out a P-XV-I slab design, in longitudinal direction, reinforced double-layer reinforcement of high-strength wires, and in transverse direction, with unstressed reinforcements.

For all the slab designs, reinforced with high-strength wires, provision was made for the use of concrete brand 400, and for slabs reinforced with a rod reinforcement of a periodic profile, brand 300.

In order to erect the prefabricated pavements on the airports and on approaches to them, they worked out typical designs of prestressed airport and road slabs of the type PAG-XIV (slab of a smooth airport) and type PDG-2-6s and PDG-1,5-6s (smooth road slab). The slabs are reinforced in the longitudinal direction with double-rowed, stressed rod reinforcements of periodic profile made of steel class A-IV, and in transverse direction with cold-drawn wires and rod reinforcements class A-II.

The airport slab PAG-XIV has dimensions in the plane of 2.0x6.0 m with a thickness of 14 cm. An installation of four rods with a diameter of 14 mm is provided for in the upper zone of the slab in longitudinal direction, and five rods with a diameter of 14 cm are provided in the lower zone. The design of road slabs PDG-2-6 s (Fig. 25) is similar to the design of the airport slab type PAG-XIV. Its difference consists in the fact that in connection with the smaller calculated load on the road pavement, the stressed reinforcment is made of rods with a diameter of 12 mm.

The road slab PDG-1,5-6s with the same thickness (14 cm) has a dimension in the plane of 1.5x6.0 m. Its reinforcements are similar to the reinforcements of the road slab PDG-2-6s, with the only difference that four stressed reinforcing rods are installed in the upper zone and three in longitudinal direction in the lower zone.

In some cases, they also use road slabs of the type PDG-1,2-6s with a dimension in the plane 1.2x6.0 m. The basic characteristics of the slabs are shown in Table 3.

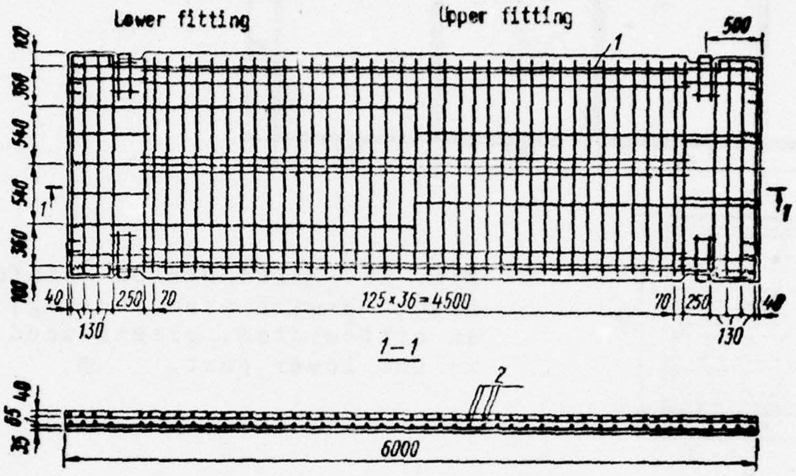


Fig. 25.--Prestressed road slab brand PDG-2-60; 1-longitudinal prestressed fitting Ø 12 mm, situated in the lower zone cf the slab; 2-transferse reinforcement in the form of welded screens.

<u>Table 3</u>

Type of slab	Dimensions in plane m	Thickness, cm	Weight, t	Concrete brand acc. to compr.	Vol. of concrete on 1 slab, m³	Expenditure of fittings, kg pre-stressed	un-stressed	general
ПАГ-XIV	2×6	14	4,2	300	1,68	68/5,7	75,9/6,3	143,9/12
ПДГ-2-6с	2×6	14	4,2	300	1,68	50,3/4,2	68,5/5,7	118,8/9,9
ПДГ-1,5-6с	1,5×6	14	3,15	300	1,26	39,1/4,3	55,7/6,2	91,8/10,5
ПДГ-1,2-6с	1,2×6	14	2,5	300	1,0	33,5/4,65	47,6/6,6	81,1/11,[illegible]

Note: The numerator indicates the expenditure of reinforcements on the slab, the denominator shows its area per 1 m^2.

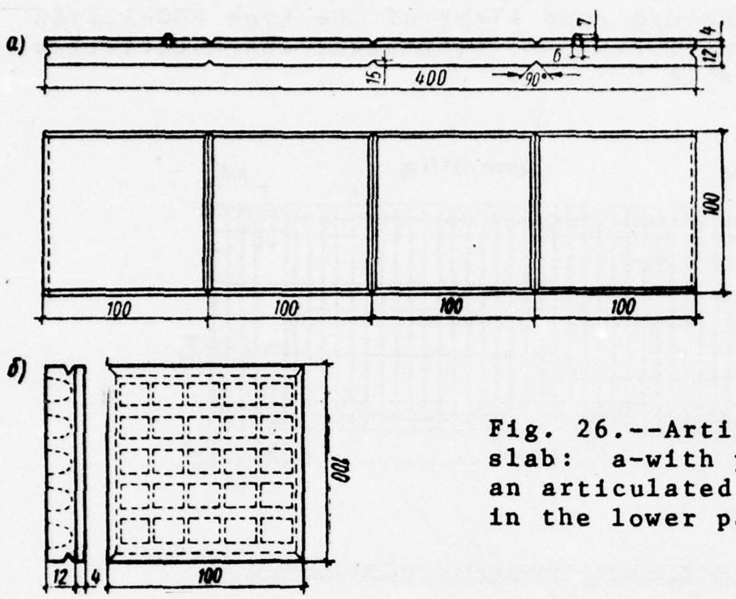


Fig. 26.--Articulared reinforced concrete slab: a-with prestressing; b-section of an articulated, prestressed slab with holes in the lower part.

Of the slabs from the PDG series, PDG-2-6s has the base operational characteristics.

In the Ural scientific-investigation institute of the academy of communal facilities RSFSR, they worked out two types of designs of articulated slabs with a prestressed reinforcement. The first design represents a massive reinforced concrete slab with the dimension 3x1x0.15 m, concrete brand 300 (Fig. 26,a). The upper compressed zone of the slab is reinforced with a stressed, high-strength steel wire of periodic profile with a diameter from 2.5 to 8 mm with a limit strength from 12,000 to 18,000 kg/cm^2. The lower elongated zone of the slab is reinforced with a screen made of unstressed reinforcements. The expenditure of concrete on one slab is 0.45 m^3. The expenditure of the reinforced steel is 12-16.5 kg or 4-5.5 kg/m^2.

The second type of design is the reinforced concrete slab with a dimension of 3x1x0.15 m, concrete brand 300. A recess is arranged in the lower part of the slab at 1/2-1/5 of its thickness, in the form of conical-shaped apertures (see Fig. 26,b). The area of the aperture cross section along the base of the slab amounts to 1/3-1/4 of its general area. The upper compressed zone of the slab is reinforced with a network of unstressed reinforcements, and the lower part with a stressed, high-strength steel wire of periodic profile with a diameter from 2.5 to 8 mm. A hot-rolled reinforcement of periodic profile of steel brands 30XG2S and 25G2S may also be used as prestressed reinforcements.

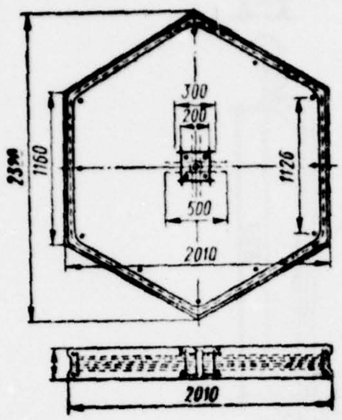


Fig. 27.--Hexagonal prestressed slab brand DNSH-2; plane and cross section.

Table 4

Group	Brand	Short characteristics	Dimensions, cm			Wt. t	Expend. per 1 m^2 slab		Distribution cost 1 m^2 slab postage paid-factory ruble
			a	b	c		Conc. $м^3$	Metal кг	
I	ДНШ-2	Hexagonal prestressed	116	201	18	1,54	0,18	2,45 / 5,70	5—58
II	ДНП-2	Rectangular prestressed	300	350	14	3,68	0,14	7,43 / 14,4	5 11
	ДНП-3	Same	300	375	14	3,94	0,14	7,10 / 14,02	5 4.

Note: Consumption of metal according to plan in the numerator, in the denominator, referred to steel class A-I.

The consumption of concrete on one slab is 0.4 m^3, the consumption of reinforced steel is 12-16.5 kg/m^2 or 4-5.5 kg/m^2.

Both types of slabs were used for constructing the city of Lower Tagil.

Such slabs are not widely used. In addition to the design defects of these slabs, it is necessary to note their manufacturing defects. Factories manufacturing reinforced concrete articles put them out, which are not yet assimilated to the technical production of such designs. As a result, we observe considerable destruction of the prefabricated pavements on constructional sections.

In accordance with the plan of typical planning of Gosstroya SSSR by the "Mosinzhproekt" institute, typical designs of prestressed reinforced concrete road slabs were worked out, the basic characteristics of which are shown in Table 4.

From what is shown in Table 4, hexagonal slabs are most used in the construction of municipal roads (group I). Of these, slab DNSH-2 (Fig. 27) has external compression, carried out along its perimeter in the process of continuous winding of a steel, high-strength wire with a diameter of 3 mm (class B-II).

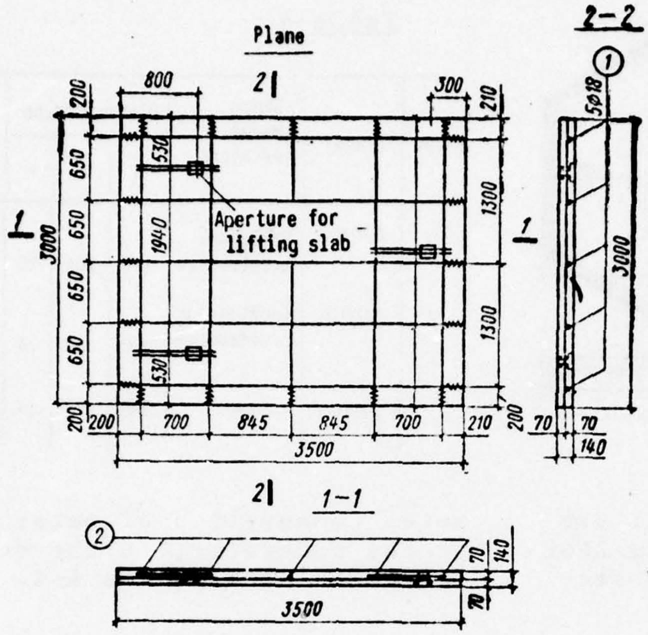


Fig. 28.--Prestressed road slab of brand DNP-2.

Road slabs of group II have a rectangular form.

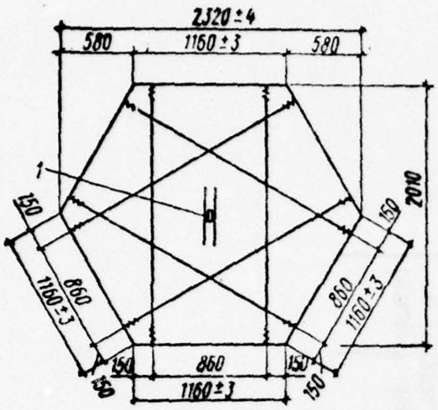
Slabs of the brands DNP-2 (Fig. 28) and DNP-3 are reinforced in longitudinal and transverse directions with a prestressed fitting with a diameter of 18 mm made of steel class A-IV. Their design is similar, the slab differing only with dimensions in the plane (3.0x3.5 m and 3.0x3.75 m). They are calculated to an automobile load of class N-30 (pressure on the wheel 6 t).

Prestressed reinforced concrete slabs were worked out as experimental designs by the institute "Mosinzhproekt", the basic data of which are presented in Table 5.

The hexagonal slab of brand DNSH-3 (Fig. 29) has side dimensions equal to 1.16 m, a thickness of 18 cm and is reinforced with a prestressed fitting having a diameter of 16 mm, class A-IV.

The rectangular slab brand DNP-3-0 is similar to the design type of brand DNP-3, the basic characteristics of which are presented in Table 4.

The prestressed slabs of brand DNP-4s (Fig. 30) and DNP-5s are reinforced in longitudinal direction with 3 rods having a diameter of 22 mm and 2 rods having a diameter of 12 mm made of steel class A-IV; in transverse direction there are 9 rods having a diameter of 18 mm. The reinforcing scheme of brands DNP-4s and DNP-5s are similar. They differ from each other only by the dimensions in the plane (7.0x3.0 m and 6.0x3.5 m).



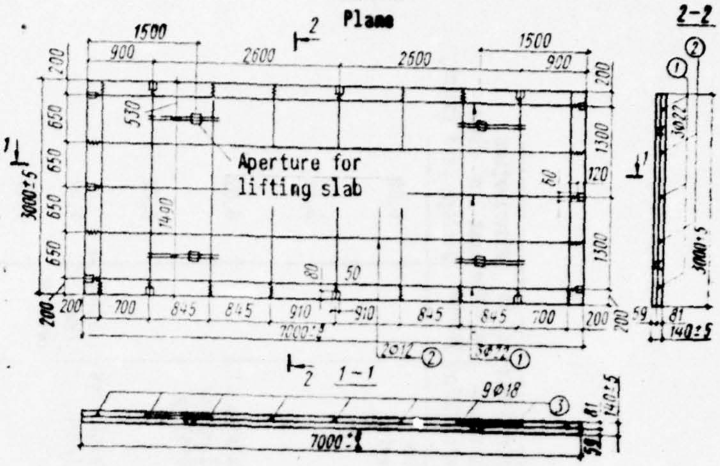


Fig. 29.--Hexagonal prestressed slab of brand DNSH-3: 1-Aperture in the slab for lifting with a clamp type ZUP-1.5 with a dimension 26x72 mm (reinforced with two rods Ø 12 mm l ≈ 510 mm).

Fig. 30.--Prestressed slab brand DNP-4-S.

The slab of brand PDG-2-6s type II is similar to the typical design of the slab of the same brand type I (Table 5). The basic difference in the slab of type II consists in the fact that this slab has two transverse channels with a diameter of 40 mm to pass through the rod or cluster-like reinforcement and its subsequent stressing in the process of installing the pavement. In addition, on the end grains there are outlets for the operating reinforcement (with a length of 130 mm) for connecting the contiguous slabs with each other after they have been laid down.

Prestressed large-dimensioned slabs of brand DNP-4B and DNP-5B are used for construction on city stressts and thoroughfares in an experimental order (Fig. 31) having dimensions of 3.0x6.88x0.14 and 3.5x5.88x0.14 m respectively.

Table 5

Group	Brand	Short characteristics	Dimensions, m	Wt. m	Vol. of concr. on 1 m^3 slab	Metal consumption, kg: connec. slab on pavement	Metal consumption, kg: on 1 slab	Metal consumption, kg: on 1 m^2 pave.	Connection of slabs: in transverse joint	Connection of slabs: in long. joints	Distribution cost 1 m^2 slabs postage paid factory
	ДНШ-2	Hexagonal prestressed	$a = 1,16$ $h = 0,18$	1,57	0,63	—	22,96	6,5	Free laying		6,30
1	ДНП-3-0	Longitudinal prestressed	3,0×3,75×0,14	3,94	1,57	—	79,53	7,10			5,43
	ДНП-4с	»	3,0×7,0×0,14	7,35	2,94	3,43	151,17	7,20	Welding of clamps or fittings		5,32
2	ДНП-5с	»	3,5×6,0×0,14	7,35	2,94	3,43	148,58	7,10			5,32
	ПДГ-2-6с тип П	»	2,0×5,74×0,14	4,0	1,61	11,7	121,30	10,5	Reinforced girder	Transverse compression	5,54
3	ДНП-4-Б	»	3×6,88×0,14	7,23	2,89	20,15	148,15	7,05			5,32
	ДНП-5-Б	»	3,5×5,88×0,14	7,23	2,89	22,15	148,67	7,10			5,32
	ДНП-4Н	»	3,0×6,88×0,14	7,23	2,89	2,61	144,81	6,95	Stressed reinforced junction	Welding of the fitting	5,32
4	ДНП-5Н	»	3,5×5,88×0,16	7,23	2,89	2,61	142,77	6,8			

The slabs are stressed in two directions: in longitudinal direction with rods having a diameter of 12 mm made of steel class A-IV, situated in two zones, and in transverse direction with rods having a diameter of 18 mm, made of steel class A-IV, situated in the middle part of the slab (along the height of its cross section).

Road slabs of brand DNP-4-N and DNP-5-N (Fig. 32) are stressed in longitudinal direction with 5 rods having a diameter of 18 mm made of steel class A-IV, and in transverse direction with 9 rods having a diameter of 18 mm differing from each other only by the dimension in the plane.

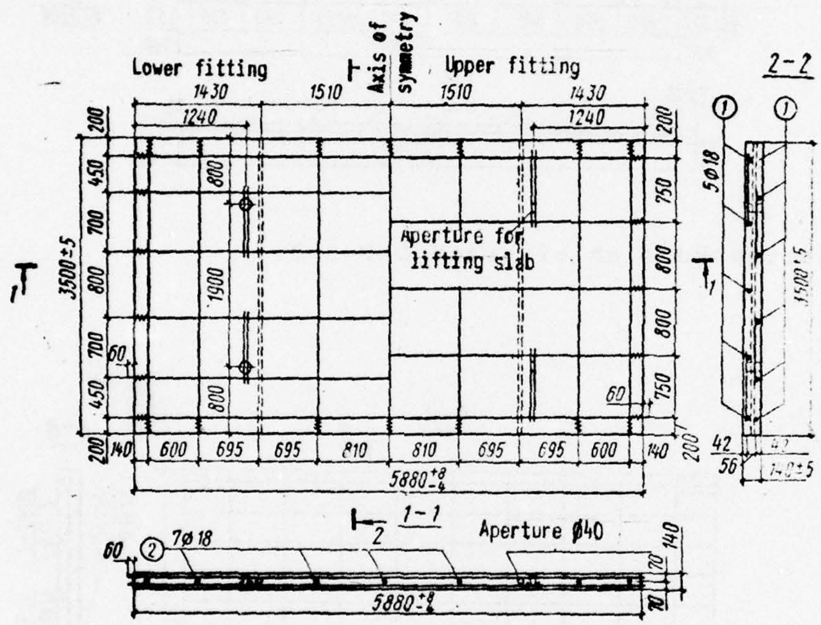


Fig. 31--Prestressed slab brand DNP-5-B.

As distinct from slabs of brands DNP-4-B and DNP-5-B, having the same dimensions in the plane, in slabs of brands DNP-4-N and DNP-5-N, the working reinforcement is situated in the center zone in transverse and longitudinal directions.

The standard load in the case of calculations for all experimental prestressed slabs is taken to be class N-30, concrete brand 400, with a frost resistance not lower than 200 cycles.

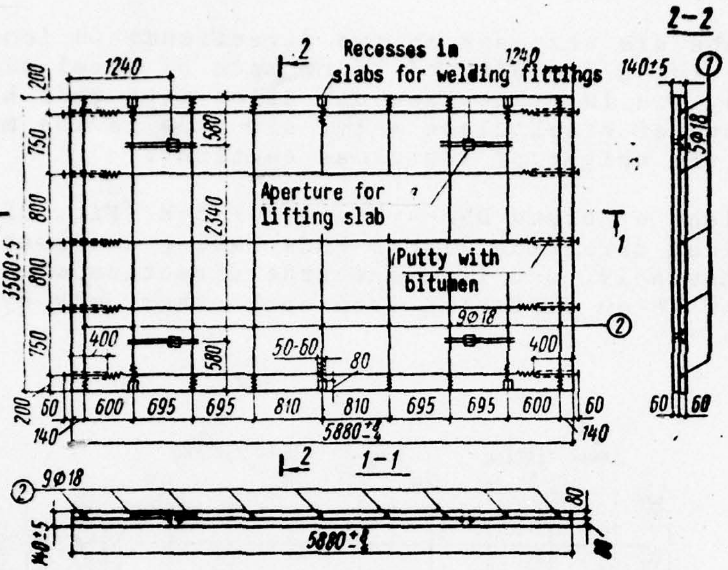


Fig. 32.--Prestressed slab of brand DNP-5-H.

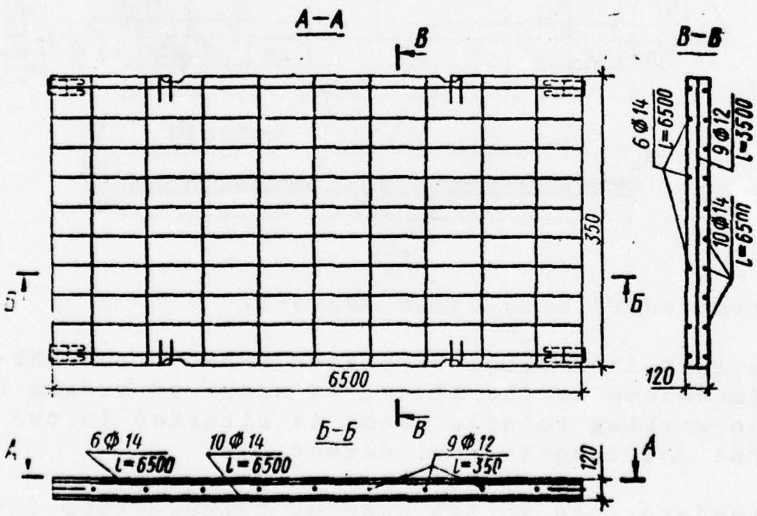


Fig. 33.--Design of a prestressed reinforced concrete slab, used in experimental construction in Moscow on the Vernadsk Avenue.

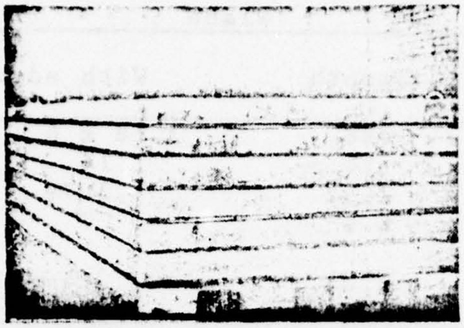


Fig. 34.--Prestressed reinforced concrete slabs with a dimension 3.0x6.0 m, made on a conveyor.

The first sections of prefabricated pavements made of large-dimensioned, prestressed slabs on city streets were constructed in 1962-1963 on Vernadsk Avenue and Michalov St. in Moscow. The design of the slabs, the technology of their manufacture and their laying were worked out by scientific workers of the department of automobile roads and the organization of the municipal services of the All-Union correspondence engineering-construction institute.

For the construction of the experimental section of the Vernadsk Ave. in the south-west section of Moscow, they worked out the slab design shown in Fig. 33. The dimensions of the slab in the plane, and also the reinforcing method were determined with regard to the technological possibilities of the equipment and transport means of the experimental factory where these slabs were made.

The slabs were reinforced with longitudinal and transverse stressed fittings in the form of bundles, consisting of four rods of high-strength, cold-drawn wire of periodic profile having a diameter of 5 mm. The bundles of the longitudinal reinforcements are situated in two rows; in the lower zones of the slab there are 9 bundles, and in the upper zone there are 5; the bundles of the transverse reinforcement are situated in one row, and along the axial cross section of the slab there are 9 bundles.

For the construction of the experimental part on Mixailov St., on the vertical conveyor of the ZHBI plant No. 6 Glavmospromstroimaterial they organized an experimental production of prestressed slabs with a dimension in the plane 3.0x6.0 m with a thickness of 14 cm (Fig. 34).

In the longitudinal direction of the slab, it is reinforced with 15 rods having a dimension of 14 mm made of steel class A-III. A screen is set up in the upper zone of the slab made of ordinary wire with a grooved surface. The dimension of the screen mesh is 200x200 mm. The slabs are made of concrete brand 400. The reinforcements are stressed electro-thermally.

Subsequently, as applicable to the technology of manufacturing on double-layer conveyors in the All-Union correspondence engineering institute, they worked out designs of large-dimensioned, prestressed slabs, the characteristics of which are shown in Table 6.

Table 6

Characteristics	Slabs	
	Smooth	With edge
Dimension in the plane, m	3x6	3.18 x 6
Thickness of the slab, cm	14	14
Consumption of concrete on 1 slab, m^3	2.52	2.79
Weight of the slab, t	6.3	7
Consumption of reinforcements on 1 m^2, kg.	8.05	8.4

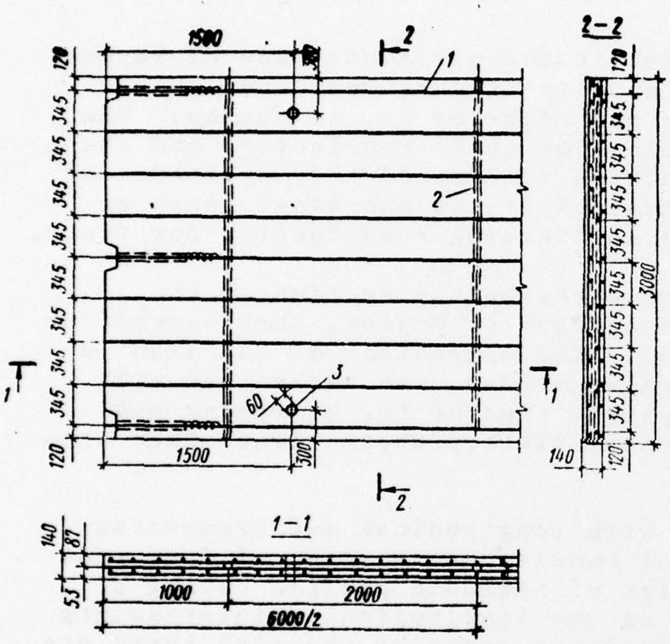


Fig. 35.--Smooth, rectangular slab: 1-operating reinforcement; 2-channels for installing transverse stressed reinforcements; 3-aperture for lifting the slab.

The reinforcements of the smooth slabs (Fig. 35) and of the slabs combined with an edge (Fig. 36) in a longitudinal direction, are provided by rod reinforcements made of class A-IV steel, stressed by the electro-thermal method. The edge and middle rods of the reinforcement have a diameter of 22 mm, intermediate ones have a diameter of 12 mm. In the transverse direction, the slabs are stressed in the process of installation with the aid of rod reinforcements having a diameter of 22 mm, let through in transverse channels provided in the manufacturing process.

In the upper and lower zones of the slab, provision is made for the installation of a reinforcing screen made of steel having a periodic profile, with a diameter of 5 mm. Manufacture of the slabs without an edge and combined with an edge is provided in all-purpose forms, thus the stressed reinforcement has the same position in the plane in both types of slabs. The versatility of the form consists in the fact that it is possible to form the same or other designs on it.

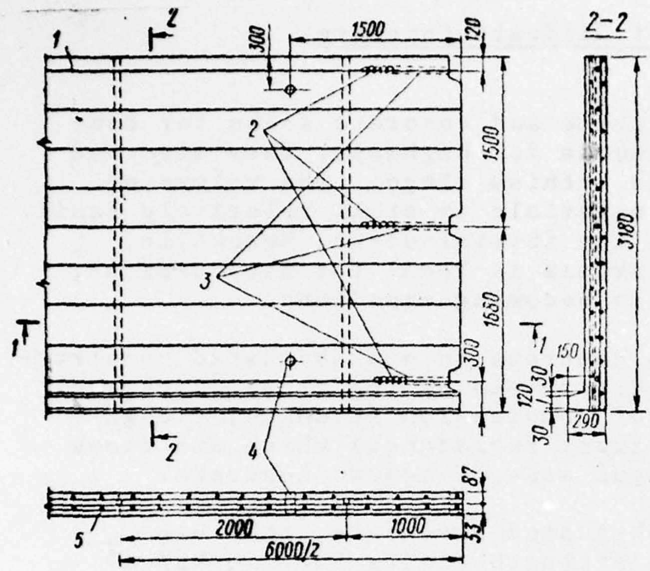


Fig. 36.--Molded rectangular slab:
1-operational reinforcement;
2-spiral;
3-tubes;
4-aperture for lifting the slab;
5-distributing reinforcement.

Moreover, in the process of manufacturing the slabs without an edge, the recess forming the edges is closed with a special detachable insert. Special recesses are provided for disposing the elements of butt connections on the end grains of the slabs (in the corners and in the middle) in the process of manufacture. An economical effectivness of the given design was set as the basis for working out a construction of a prestressed slab combined with an edge. When building prefabricated pavements from slabs having an edge, labor consumption and a small mechanized operation is eliminated by setting up an edge rock. Such a design increases the strength of the slab edges and eliminates the penetration of moisture in the base in the molded part of the prefabricated pavement.

In the practice of road construction, there are occasions to use slabs of prestressed reinforced concrete of much larger dimensions. So, on the Karlsruhe-Stuttgart road in 1957 they laid down small sections of prefabricated pavement made of prestressed, reinforced concrete slabs having dimensions 12.50x3.74x0.18 and 9.99x3.74x0.18 m [33]. Prestressing of the reinforcements was set up only in longitudinal direction. For slabs with a length of 12.50 m, it amounted to 30 kg/cm^2 and for slabs with a length of 10 m (9.99 m) it amounted to 23 kg/cm^2. As subsequent studies showed, if a part of the tensile stresses are transmitted to the concrete of the slabs, then the value of the pre-stress for given designs may be reduced to 12 kg/cm^2.

Unstressed reinforcements were installed to take up the transverse stresses with elongation at bend along the lower and upper grains of the slabs.

5. Prefabricated Pavements made of Silicate-Concrete and Slag-Lithium Slabs

In addition to reinforced concrete and concrete slabs for constructing rigid prefabricated pavements for highways, they also use slabs made of silicate concrete and lithium slags. The volume of construction in pavements of such materials is still relatively small. Working out designs of slabs is in the initial stage. Meanwhile, the use of slabs made of these materials is local for many regions, but their technology and economy are becoming expedient.

The region of use of silicate concrete in prefabricated constructions to a considerable degree is determined by the strength characteristics of their design (limits of compression strength, elongation at bend, resistance to wear, frost resistance) which are close to the strength properties of designs made of cement concrete.

To manufacture slabs of prefabricated pavements, they use silicate concrete with compression strength limits 500-350 kg/cm^2 and elongation at bend 60-50 kg/cm^2. These limits may be increased with appropriate selection of the mixture composition and by increasing the quality of the astringent grist, the forming and the autoclave processing of the articles.

Silicate concrete is characterized by a better ratio of elongation at bend strength to compression strength than cement concrete. Moreover, it is rather frost resistant (it withstands 100-200 and more cycles of freezing and thawing).

The experience of civil engineering gives evidence of the possibility of making reinforced, prestressed constructions of silicate concrete.

According to the data of some authors [8], thanks to the high temperature of processing articles made of silicate concrete in the autoclaves and the difference in the coefficients of linear expansion of the reinforcements and of the silicate concrete in ordinary reinforced articles, spontaneous stressing of the reinforcements frequently occurs, which increases the strength and the crack resistance of these articles. The positive influence of spontaneous stressing of the reinforcements appears especially in the first period after manufacture of the articles. Subsequently, creep and shrinkage of the concrete reduces the stress value of the reinforcement and compression of the concrete.

According to the economic indicators, the articles made of silicate concrete successfully compete with articles of cement concrete.

In a series of cases, the cost of the silicate concrete is 25-35% lower than the cost of sement concrete. The use of silicate concrete in regions not provided with rock material is especially practical (useful for cement concrete). Sands useful for manufacturing silicate concrete are more widely dispersed than other rock materials. There are sand deposits in almost all regions not having stone material. Sand and lime is usually almost half as cheap as crushed stone and cement.

A reduction of the transport costs provides considerable economy, due to the use of local materials as well as due to a reduction in the weight of finished silicate-concrete articles. The volumetric weight of concrete is equal to 2.0-2.2 t/m^3, which is 10-20% less than the volumetric weight of cement concrete.

Articles made of reinforced and non-reinforced silicate concrete at the present time are used mostly in civil and industrial construction. Silicate concrete has begun to be used in the USSR for the construction of prefabricated road pavements on an experimental scale since 1962 on short road sections.

Slabs made of silicate concrete are used for the construction of pavements of the permanent as well as the temporary types. In 1962, near the city of Tallina, they constructed a gauge pavement made of slabs having dimensions 3x1x0.18 m on a crushed rock base having a thickness of 25 cm and levelled out with a 3-5 cm sand layer. The pavement was operated for nine months with a traffic intensity up to 1000 MAZ-205 automobiles per day, after which it was dismantled and the slabs were used on other objects.

Reinforced slabs with dimensions 2x1x0.16 m were laid directly on the ground on one of the forest roads Estonskoi SSSR in the year 1964. The expenditure of reinforcements amounted to 9.8 kg/m^2. The contiguous slabs were connected to each other with horizontal, wooden pegs 5x5 cm, which were hammered into the side in a recess on the end of the slabs. Slabs of similar design were also used in constructing forest roads in the Kalinin region. Here, they were laid on a gravel-sand base with a thickness of 20 cm.

In 1964, in Western Siberia on a road of the IIIrd technical category in the Omsk-Sherbakul region, they constructed an experimental section of reinforced pavement (Fig. 37) made of articulated, silicate concrete slabs (designer P.P. Kovalenko). Slabs with a dimension 3x1x0.18 m were made of aluvial sand with a mean coarseness and slaked lime with an activity of 66.5% (CaO+MgO). The brand of the silicate sement was 300-400, the expenditure of reinforcements was 9.27 kg/m^2. The prefabricated pavement was laid on a cement-sand base with a thickness of 16 cm. Above the base, they constructed an even layer with a thickness of up to 5 cm of a dry cement-sand mixture having a composition 1:10. The spaces between the slabs were filled with bituminous mastic.

Fig. 37.--Prefabricated pavement made of silicate-concrete slabs on the Omsk-Sherbakul road.

According to the data of the Omsk affiliate SoyuzDorNII (Yu. N. Visotskii), after five years of use, the prefabricated pavement of this section is in good condition. For this period, it carried more than 1.5 million automobiles with an average tonnage at an average stable traffic intensity of the order of 1000-1700 automobiles. When measuring the smoothness of the pavement, the clearance under the three-meter gage did not exceed 5 mm. The average annual wear of silicate-concrete slabs, measured with the aid of brass markers embedded in the pavement, amounted to 0.1-0.5 mm.

In 1966, in the Tyumensk region on the approach to the Tyumen-Tobolsk road, they constructed an experimental section of prefabricated pavement made of reinforced silicate concrete slabs having different dimensions in the plane: 2 x 1; 3x1 and 4x1. The thickness of all the slabs was the same 16 cm. The brand of the silicate concrete was 300-400, the expenditure of reinforcements was 7.05 kg/m^2.

On this section, the slabs were laid in the winter time on a crushed rock base having a thickness of 15 cm and evened out with a layer of dry, cement-sand mixture with a 1:8 composition having a thickness of up to 5 cm. The slabs for this section were made of local, fine-grained sand. A two-year observation of this section showed that the wear of the silicate-concrete slabs, made of fine-grained sand, was greater than the wear of the slabs made of medium-grained sand. With a daily intensity of 1500 automobiles and more, (mostly heavy ones), the wear of the silicate concrete slab amounted to 0.2-0.4 mm per year.

Obviously, with the use of fine grained sants for silicate concrete on sections with heavy and intense traffic, it is necessary to construct a protective layer on the pavements made of bituminous-mineral or other materials.

Silicate-concrete slabs are also used for reinforcing work.

In 1964, on the Moscow-Kuibishev highway, at the approach to the city of Penz, a reinforcing strip was laid down along the travelled part made of silicate-concrete slabs of two types: non-reinforced with dimensions of 1x0.5x0.2 m and reinforced with dimensions 1x0.5x0.16 m

with a consumption of reinforcements 17.8 kg/m^2 [1]. White, silicate-concrete slabs sharply differ from dark, asphalt-concrete pavement and serves as a good orientation for drivers, especially at night, which increases traffic safety.

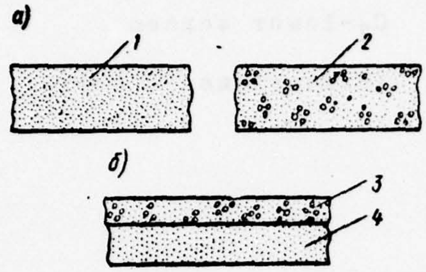


Fig. 38.--Silicate-concrete slabs: a-single-layer for bases and pavements of road toppings: 1-of fine-grained concrete; 2-of large-grained concrete; b-double-layer for pavements of road toppings; 3-upper layer of fine-grained concrete; 4-lower layer of fine-grained concrete.

The slabs are laid down on a natural base made of sandy-silty soil as well as on an artificial base made of sand with a thickness of 20 cm and of crushed rock having a thickness of 10 cm. The slabs are connected to each other by welding metallic inserted parts. The spaces are filled with bituminous cement.

The travelled part of the road with an asphalt-concret pavement on this part has a width of 6 m. With a high traffic intensity (more than 5000 automobiles per day), frequent cases of automobiles driving onto the reinforced strips are unavoidable. Observations on the reinforced strips of silicate-concrete slabs show that the feinforced slabs layed on a crushed rock base are in the best condition, which are connected to each other by welding inserted parts. Cracks appear on individual, non-reinforced slabs.

The first standardized document on the use of prefabricated pavements made of silicate-concrete slabs in road construction was researched and published in 1968 by the Omst affiliate Soyuz-DorNII. [Recommendations on the use and technology of production of silicate concrete in the conditions of Western Siberia (Yu. N. Bisotskii, N.I. Xlopov]. The design and the calculation of silicate-concrete slabs is recommended to be carried out basically like the design and calculation of slabs made of cement concrete.

For the manufacture of the slabs they used fine-grained and large-grained silicate-concrete mixtures. As a filler in the fine-grained silicate concretes they used sand, in the large-grained ones they used sand with a crushed rock fraction of 5-10 and 10-20 mm.

The slabs made of silicate-concrete may be double-layered and single-layered (Fig. 38). The single-layered slabs are formed of homogeneous, fine-grained or large-grained mixtures. They are used for constructing pavements as well as for the bases of road surfaces. In the double-layered slabs, the lower layer is made of fine-grained mixtures, and the upper one, with increased wear resistance, having a thickness of about 5 cm, is made of large-grained mixtures of assorted composition. The two-layered slabs are used only for constructing pavements.

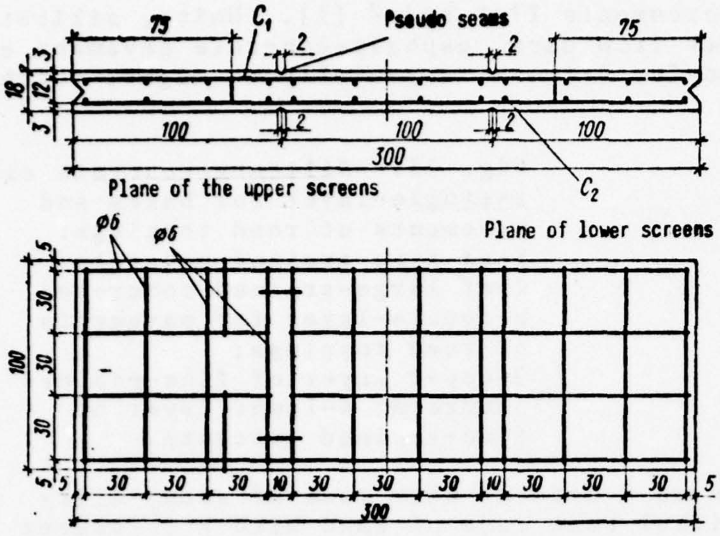


Fig. 39.--Reinforcing scheme of silicate-concrete slabs: C_1-upper screen; C_2-lower screen (dimensions in cm).

The dimensions of the slabs in the plane are usually limited by the autoclaves used for their manufacture. In the majority of cases, the width of the slab is assumed to be equal to 1.0-1.5 m, the length from 1.0 to 6.0 m. In the past few years, domestic industry has produced autoclaves with a diameter up to 3.6 m, with a length up to 27 m. The presence of such autoclaves makes it possible to manufacture silicate-concrete slabs of much larger dimensions.

The junctions of the silicate-concrete slabs in prefabricated pavements are recommended to be made as the rigid type. The outlets of the reinforcement in the junctions are connected by welding or with special connecting devices of similar construction, used in the junctions of concrete and reinforced concrete slabs. The junctions are filled with cement of the same compounds, which were used for building prefabricated cement-concrete pavements.

The number of reinforcements and their placement in the slab are determined by the calculation in the reinforced concrete slabs. Fig. 39 shows the scheme of reinforcement of silicate concrete slabs of a prefabricated pavement of the Omsk-Sherbakul road.

The prefabricated pavements of silicate concrete slabs are usually constructed on bases of crushed stone, gravel or ground, reinforced with binding materials (bitumen, sement). To guarantee the required smoothness, and also to create a tight contact between the base and the lower surface of the slabs on the base, a thin (3-5 cm) smooth layer of sand is put down, or a dry cement-sand mixture or sand, processed with liquid bitumen. The silicate-concrete slabs of prefabricated bases are laid on an underlying layer of sand, gravel or crushed rock materials, and also of reinforced dirt.

A levelling layer is placed above the underlying layer, except for those cases when the underlying layer is made of sand.

The prefabricated pavements may also be made of lithium, slag slabs. The casting of the slab blocks of relatively small dimensions is accomplished in the USSR on the Lower Tagilsk, Zhdanovsk and other metallurgical plants. Parts of sidewalks made of lithium slab blocks are still in good condition after 70-80 years. There is experience in many countries in the use bridges made of lithium slab blocks.

In 1954, in the SoyuzDorNII (O.A. Yakinin, V.K. Nekrasob) they carried out experimental work in casting slabs with dimensions 1.75x1.50x0.16 m from blast furnace slabs. The experiments showed that the strength on elongation at bend and compression is 1.5-3.0 times higher than in the case of cement-concrete slabs. Under laboratory conditions it is possible to reach the limit compression strength 4000-5000 kg/cm^2 and elongation at break 400-500 kg/cm^2.

The high strength characteristics make it possible to reduce the thickness of the slabs, reduce the material expenditures and cost of transportation. In regions where metallurgical plants are located, the cost of lithium slag slabs is 2-3 times lower than the cost of full-strength concrete slabs of the same dimensions.

However, in the construction of slag-lithium slabs, there are still many unsolved problems in the technology of their manufacture and installation. The special features of their work under contemporary moving loads has not been studied. All this prevents the use of slag-lithium slabs in road construction, thus up to now they have not been widely used.

6. Prefabricated Pavements made of Asphalt-Concrete and Bitumen-Mineral Slabs

Piece products made of different mixtures of mineral material and organic astringents for highway pavements, sidewalks and streetcar tracks have been used for a long time. In the seventies of the past century, experimental sections of highways were built in Moscow made of small-dimensioned slabs, manufactured from pressed, natural asphalt. At the beginning of the 20th century, blocks made of tamped asphalt were laid on the streets of the city of Tiflis.

In 1940, asphalt slabs with a dimension of 25x25 and 25x12 cm with a thickness of 3-6 mm were laid in Moscow. These slabs were made at a brick factory.

Small-dimensioned asphalt-concrete slabs are convenient for laying in constricted places where the usual asphalt laying and rolling for the construction of asphalt-concrete pavements cannot be used. The small dimensions of asphalt-concrete slabs were determined for two reasons: the weight limit, making manual laying possible, and low resistance of asphalt-concrete to elongation at bend. Large-dimensioned slabs deform in the process of transportation and installation under the effect of gravity.

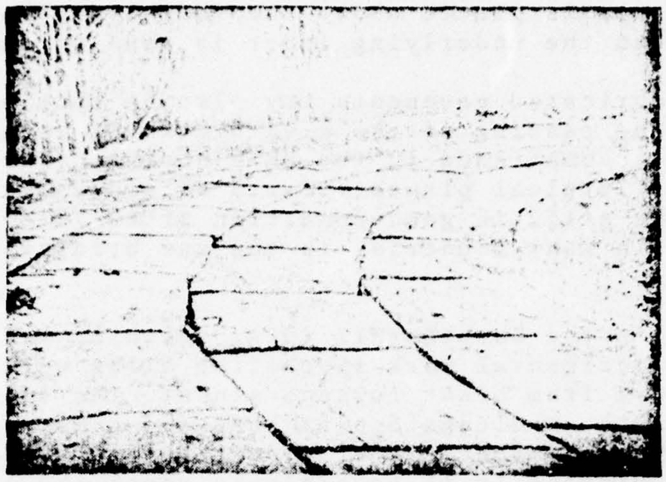


Fig. 40.--Base made of bitumen-mineral slabs.

Asphalt-concrete slabs are laid on the same base as monolithic asphalt-concrete pavements. In a series of cases, under the effect of traffic in the warm season of the year, the slabs gradually assumed mutual cohesion and the prefabricated pavements were converted into monolithic ones, having smaller cross sections at the junction sites.

Despite a series of advantages, prefabricated asphalt-concrete pavements made of small-dimensioned slabs have het been widely used. To a considerable degree, this is explained by the absence of mechanization means for making the slabs, as well as for laying them.

Bitumen-mineral slabs of medium dimensions, intended for building the upper layers of bases and the lower layers of highway pavements have been much more successfully introduced into production. The construction and manufacturing technology as well as the laying of such slabs was worked out by doctoral candidate A.S. Rostovtsev and the Siberian automobile-highway institute in the name of V.V. Kuibishev [26]. Similar designs were also worked out by the Sverdlovsk scientific-investigation institute of the forestry industry.

At the present time, more than 300,000 m^2 of prefabricated bases made of bitumen-mineral slabs (Fig. 40) have been laid on the roads of Siberia and the Urals. Slabs with dimensions in the plane of 1.74 x 2.99 m with a thickness of 14-20 cm have been more widely used. The dimensions were taken in accordance with the breaking up of the travelled part with a width of 7 m on 4 longitudinal strips (about 1.75 m) with reductions to 1 cm for the junctions. Slabs of such dimensions are laid with their long side along the road axis.

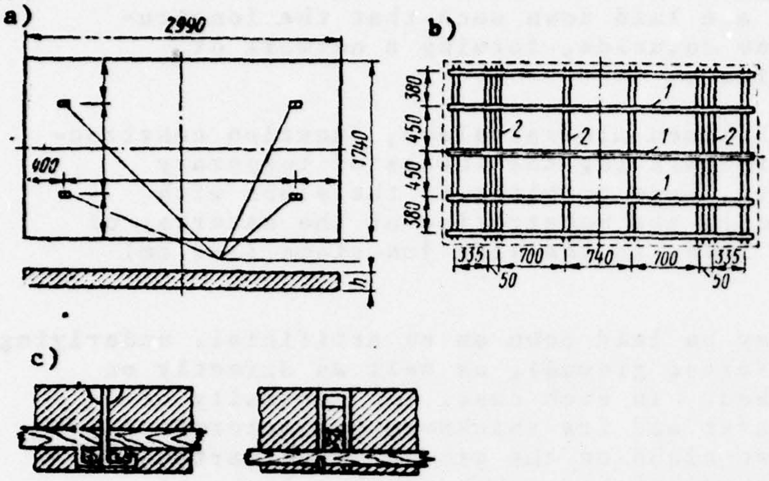


Fig. 41.--Design of bitumen-mineral slabs with dimensions 2.99x1.74 m: a-plane of the slab; b-Plane of the wooden framework; c-Fastening piece of the installation eyelet: dimensions of the blocks: 1-40x40 mm; 2-30x40 mm; h of the slab 140-200 mm; diameter of the steel mounting eyelet d=8 mm.

The slabs may be made of two dimensions. For example, with a width of the travelled part of 7.5 m, they should be made with dimensions of 1.87 x 2.99 m. Slabs with dimensions in the plane of 2.0x3.0 m were also used for constructing the bases on squares. To construct gauge forest roads they used slabs of 1.0x2.5 m.

In bitumen-mineral slabs, as opposed to concrete and reinforced concrete ones, the largest bending moments occur not in the pavement under the effect of a moving load, but in the period of construction, with their loading onto transport media, and reloading in the process of installing the prefabricated bases or pavements.

The slabs are reinforced with a reinforcing framework in order to take up the tensile forces at bend. Considering the short time of its work (up to the conclusion of laying the slabs in the road surfacing), the framework is usually made of thin wooden strips. (Fig. 41). It is connected with wire loops by which the slabs are picked up by the crane. It is also possible to reinforce the slabs with waste products of a metal reinforcement, with fiberglass, and with other materials capable of absorbing the tensile stresses.

Since with the lowering of temperature the rigidity of the bitumen-mineral slabs greatly increases along with their ability to take up the tensile forces without destruction, then it is rational to carry out all the operations of their transport and laying in cold weather. In individual cases, when performing all the work of making the slabs, their transport and installation in periods of low, negative temperatures, reinforcing of the slabs can be dispensed with.

On straight parts of the road, when constructing continuous bases, bitumen-mineral slabs are laid down such that the longitudinal and transverse junctions coincide, forming a network of intersecting, perpendiaular lines.

In the construction of bitumen-mineral slabs, junction constructions are not provided for transmitting the forces of temporary load from one slab to another. Some coupling of the slabs with eahh other takes place thanks to the penetration of the material of the overlying (smoothed out) layer in the wide junctions (1-3 cm) between the slabs.

Bitumen-mineral slabs may be laid down on an artificial, underlying layer (of sand, gravel, reinforced ground), as well as directly on the ground of an earth road bed. In each case, the necessity of constructing an underlying layer and its thickness are determined by calculation. When laying down slabs on the ground of an earthen road bed, it is usually smoothed out beforehand with a layer of sand having a mean thickness of 5 cm. Bitumen-mineral slabs are unsuitable for dismantling because of their low degree of rigidity and are not suitable for repeated use, thus they must be used in the construction of road surfaces with a long period of use.

The basic positive qualities of bitumen-mineral slabs are:

the use of local sand and gravel-sand materials for their manufacture;

the possibility of manufacturing them at road, asphalt-concrete plants in winter time without a great deal of additional expenditure;

the possibility of transporting and laying the slabs in road surfaces during the winter.

In the majority of cases, all this guarantees an economic merit in using bitumen-mineral slabs in regions where winter lasts for a long time, and where the supply of stone materials is insufficient.

The greatest technical disadvantage of prefabricated layers of road surfaces made of bitumen-mineral slabs is the unevenness of the surface.

Bitumen-mineral slabs have considerable plasticity especially in winter time. Thanks to this, they fit tightly against the base and have contact with it at any point of the lower surface of the slab. By this, they differ from the rigid concrete and reinforced concrete slabs. But, at the same time, due to their high plasticity, they do not maintain the evenness of the surface, which they have when they are manufactured and they deform, to a considerable degree following the unevenness of the lower-lying surface, and sometimes even accentuating it. All this limits their possibility of use, especially on roads of high technical categories. These slabs also may not be used for constructing the upper layer of the pavement.

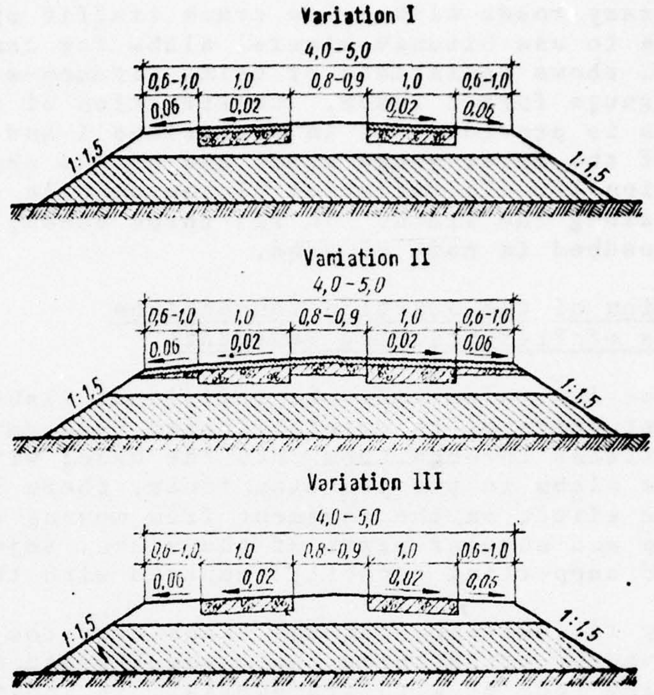


Fig. 42.--Gauge, prefabricated pavements made of bitumen-mineral slabs (dimensions in m).

When using such slabs as a base, it is necessary to construct a levelling, monolithic layer of a fine-grained, bitumen-mineral layer along the surface of the slabs which complicates and makes the carrying out of the work more costly.

Ordinary bases made of bitumen-mineral slabs, after laying, remain exposed for a period of 3-4 weeks, and more, in the warm season of the gear, while slabs under the effect of gravity do not fit tightly with the underlying layer. To hasten this process, it is useful to open truck traffic along the slabs. After completing of the slab deformations, a levelling layer of a fine-grained bitumen-mineral mixture is placed over them. The surfaces may be constructed only after this.

It is most expedient to use bitumen-mineral slabs on city streets for constructing the bases of road surfaces on streets with a small amount of intense traffic, on passages between and within the blocks, and also on special industrial roads.

On temporary roads with a low truck traffic speed, as an exception it is possible to use bitumen-mineral slabs for constructing the pavement. Fig. 42 shows variations of using bitumen-mineral slabs for pavements of gauge forest roads. Construction of a levelling layer over the slabs is provided for in variations I and II. Also, reinforcement of the inter-gauge space and of the shoulder are provided for in variation II. In variation II, automobile traffic is provided for directly along the slabs. In all three cases, the upper part of the earthen roadbed is made of sand.

7. Construction of the Junction Connections and Joints of Prefabricated Pavements

The places for connecting the individual slabs with each other are the weakest parts of the prefabricated road pavements. Surface moisture penetrates through them into the base; with settling and warping of the slabs in the junction zones, there is a great increase in the dynamic effect on the pavement from moving automobile transport; the edge and angular parts of the slabs, adjoining the junctions, have a reduced supporting capacity compared with the average zones.

Providing full-strength of the slabs over the entire area is usually achieved by reinforcing their angular and edge sections with reinforcing rods or with frameworks. In individual cases, recourse is taken to thickening the edges of the slabs. Also, the design of the junctions is of essential importance in creating equal strength of the entire prefabricated pavement.

The stable position of the slabs under traffic is guaranteed by firmly supporting their base as well as with junction connections, connecting adjacent slabs with each other. The junction connections must prevent mutual shifting of the slabs in height and must guarantee redistribution of the forces between the loaded slab and those adjacent to it. Partial unloading of the angle and edge parts of the slab takes place when fulfilling the latter requirement, which are experiencing the effect of temporary load.

All the joints between the slabs of prefabricated pavements of the permanent type must be water-impermeable and must protect the underlying layer of the road surface and of the ground road bed from moisture penetrating into it.

In the majority of designs, provision is made for filling the junctions with asphalt mastic, with cement solutions or other insulating materials. Divergence from this requirement is permitted in the pavements of park roads, prefabricated bases under improved pavements and also in pavements of temporary roads with short service lives.

Junction designs used at the present time can be divided into three basic groups according to the character of their work under load: (Fig. 43): articulated (1-4), elastic-pliable (5-7) and rigid (8-10).

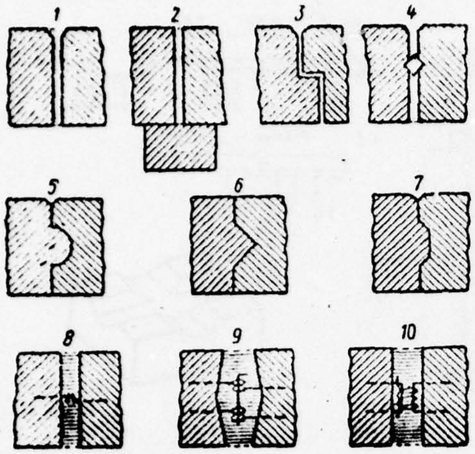


Fig. 43.--Designs of joint connections in prefabricated pavement slabs:
1-connection with butt end "butts";
2-connection on foundations;
3-connection "in quarter";
4-dowel connections;
5,6,7-grooved connections;
8-connection with a weld or with screwing together of the reinforcement;
9-connection of the reinforcement eyelet with a dowel;
10-connection of the reinforcing brackets with a helix.

In designs 1 and 2, the slabs are jointed with vertical grains, the junction between them is filled with asphalt mastic or with a cement solution. In design no 2., the slab edges are supported on a special foundation. Design no. 3 provides the transmission of forces from one slab to the other, but only in one direction, with the movement of traffic from right to left. In design no. 4, the slabs are connected with a wooden dowel, with a cement solution or another material.

The working conditions of the slab edges with junctions of the first design are close to the working conditions of slabs connected with articulations. Such slab connections do not take up the bending moments and do not provide equal strength of the edge parts of the slabs compared with the middle parts. Considerable sagging may emerge under the effect of vertical loads at the junction sites with articulated connections, as a result of which tensile forces form in the upper edge layers of the slabs, leading to the formation and detection of cracks. In the process of exploitation, with the combined effect of transport and temperature, shifting of the slabs frequently takes place along the base disrupting the work of joints of this type. The advantage of design 1 is its simplicity. Such designs are usually used in pavements of temporary roads.

In elastic-pliant joint connections (designs 5, 6 and 7), provision is made for the construction of grooves and slots of different types. These connections are insufficient to guarantee the stability and evenness of prefabricated pavements. However, with a high quality of slab manufacture and with careful carrying out of the installation work, they may absorb part of the calculated bending moment. The basic shortcomings of joints with groove connections is the complexity of making the slabs, and also the difficulty of performing the installation works in constructing the pavement. Grooved junctions are usually used in the construction of prefabricated pavements from slabs having small and medium dimensions.

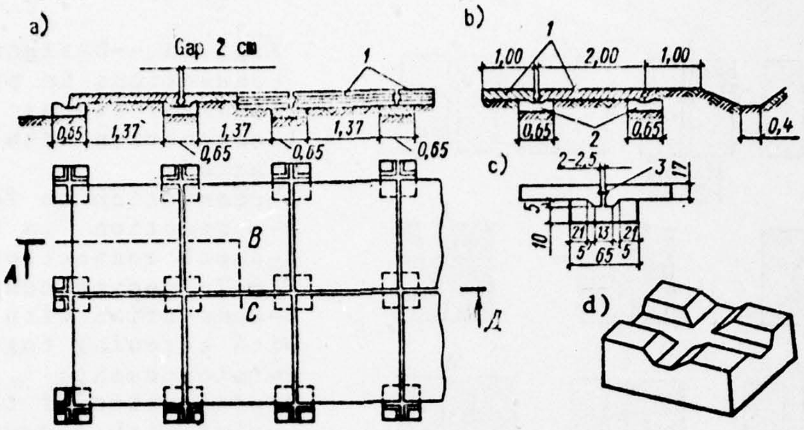


Fig. 44.--Slabs with dowel connections laid on figured, angular foundations: a-cross section along ABCD; b-detail adjoining the pavement to the shoulder; c-detail of the junction; d-angular foundation (locking slab); 1-Slabs; 2-Foundation; 3-Dowel.

3 variations in the designs of rigid junctions are shown in the third group. In design 8, the ends of the functioning reinforcements are rigidly connected by welding or with special threaded couplings. In design 9, the eyelets on the ends of the reinforcing rods are connected by metal dowels. In design 10, the reinforcing brackets, issuing from the grains of contiguous slabs, are connected with a steel helix. In all the designs, the interstices between contiguous slabs are filled with a cement solution after connection of the reinforcements.

Solid junction connections make it possible to eliminate articulations in the zone of the junctions, which facilitates increasing their strength and crack stability and with a corresponding design of the junctions, provides the possibility of obtaining a solid, non-articulated pavement from the prefabricated elements (slabs) of considerable length and width.

One of the most improved designs for the solid connection of slabs should be considered pre-stressed joining. Its use is especially practical in building prefabricated pavements from large-dimensioned, pre-stressed reinforced concrete slabs. The more characteristic examples of the designs of different joint connections of slabs for prefabricated pavements are examined below.

Fig. 44 shows the laying of square, reinforced concrete slabs with dimensions 2.0x2.0 m on angular foundations with their simultaneous connection to each other with dowels. The presence of the foundation increases the carrying capacity of the angular parts of the slabs.

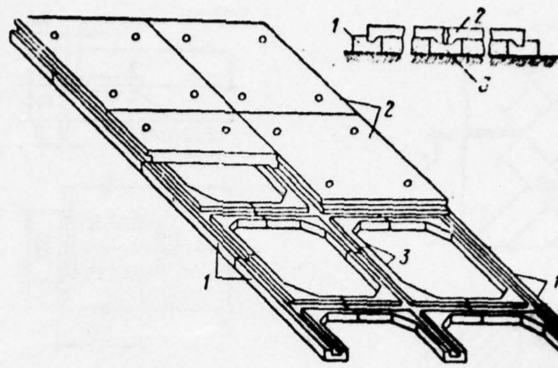


Fig. 45.--Prefabricated pavement with side foundations and cross pieces. 1-Foundation; 2-Slab; 3-Crosspiece

Fig. 46.--Prefabricated pavement supported on a system of longitudinal and transverse beams.

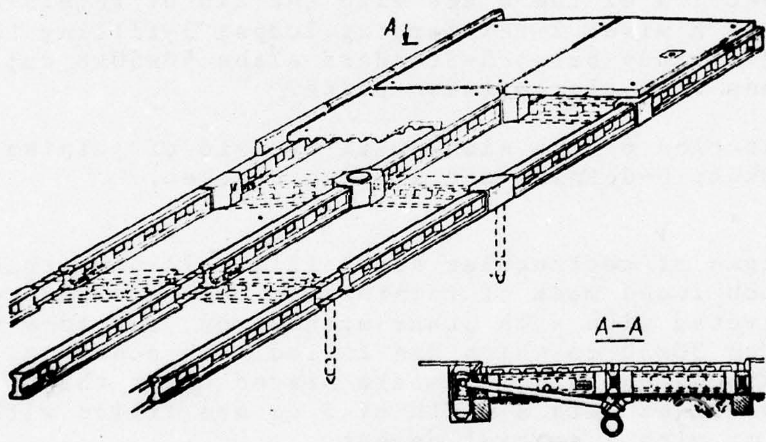
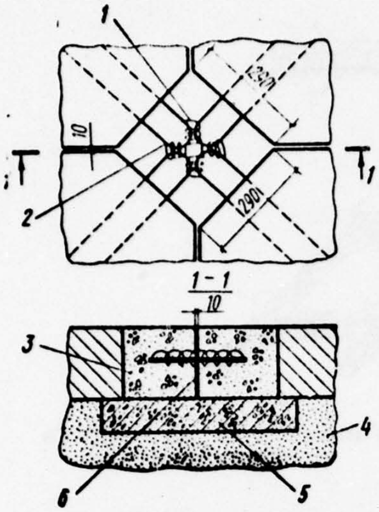


Fig. 45 shows the designs of prefabricated pavements from slabs of the system of A.V. Yakovlev under heavy load (30 t on the axis) for temporary roads on weak soil. The slabs are laid down on a prefabricated, reinforced concrete framework consisting of ffameworks and crosspieces.

In Switzerland, a road pavement was constructed with the use of large reinforced concrete slabs (with a dimension in the plane 3.5 x 7.0 m), supported on a system of longitudinal and transverse beams (Fig. 46).

Similar designs of prefabricated pavements are supported on longitudinal frameworks developed also by the department for the organization and mechanization of the road-construction work of the Kiev automroad institute under the direction of Prof. V.A. Rudenko.



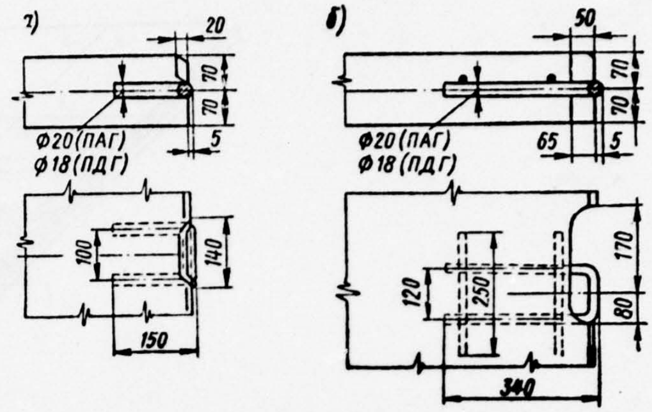


Fig. 47.--Connection of the slabs with the aid of reinforcing loops: 1-connected with a wire; 2-reinforcing loops; 3-filling the recesses with concrete; 4-sandy base; 5-Standard slabs 50x50x8 cm; 6-Pouring of the junctions with clay-bitumen paste.

Fig. 48.--Connection of the slabs with the aid of joining brackets: a-Joining bracket; b-Joining and lifting bracket.

Some designs of rectangular slabs (Fig. 47) have chamfered corners in which loops made of reinforcing rods are placed. The loops are connected with each other with wires, and form units with a dimension 30x30 cm which are filled with concrete. Standard slabs with a dimension 50x50x8 cm are placed under the corners of the slabs. Junctions with a width of 1 cm are filled with a clay-bitumen paste or with a special cement.

Junction connections of slabs with the use of brackets, made of round reinforcing steel with a diameter 20 mm (Fig. 48) are used in the construction of reinforced airport pavements. Such connections are used, in particular, in prestressed slabs of types P-XIV, P-XV-I, P-XV-III, PAG-XIV, PDG-2-6s, PDG-1,5-6s, PDG-1,2-6s.

With installation of the prefabricated pavement, the brackets of contiguous slabs, situated in specially made recesses of the butt end and side grains, are welded to each other. The brackets placed on the butt end grains, are intended only for connecting the slabs.

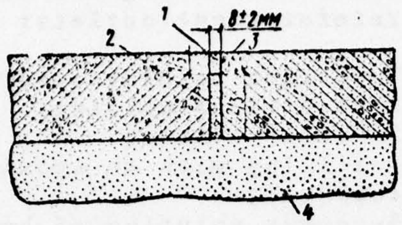


Fig. 49.--Laying slabs without joint connections:
1-"Izol" cement;
2-cement solution brand 400;
3-coating with primer;
4-sand, processed with bitumen or with cement.

The brackets on the side grains are also used for lifting the slabs. Such a combination does away with the construction of special lifting loops which reduces the expenditure of reinforcing steel.

The typical and experimental slab constructions worked out in 1965 by the planning institute "Mosinzhproekt" for mass and experimental construction of prefabricated pavements on city thoroughfares and streets, have several methods of connection:

I-free laying;
II-welding of the brackets or of the reinforcement outlets;
III-connection with a "reinforcing beam;
IV-stressed reinforced junction.

According to the first method, the slabs are laid freely, i.e. without mutual connection (Fig. 49).

According to the second method, the connection between the slabs is accomplished by means of welding the ends of the working reinforcements, situated in special recesses (Fig. 50), or by means of welds of the junction and lifting brackets.

According to the third method, the connection of the slabs in longitudinal direction is accomplished by means of welding the ends of the working reinforcements projecting on the butt end grains of the slabs, by additionally laying a transverse rod reinforcement in the junction and subsequently filling the space formed between the slabs with concrete. Such a connection (Fig. 51) is called a "reinforcing girder". After coating the side grains with cement, the slabs are braced in transverse direction with rods or with wire bundles, passed through the transverse channels of the slabs.

According to the fourth method, the connection of the slabs is accomplished in longitudinal direction by welding the outlets of the working reinforcements with each other with subsequent stressing of the joints with the aid of wedge-shaped jacks (Fig. 52).

In the practice of constructing prefabricated road and airport pavements, different methods of construction are encountered in the case of pre-stressed junctions. One of the best known methods of stressed joining is connection of unstressed concrete and reinforced concrete slabs of small dimensions with the aid of a through reinforcement let through the channels of these slabs, with its subsequent stressing.

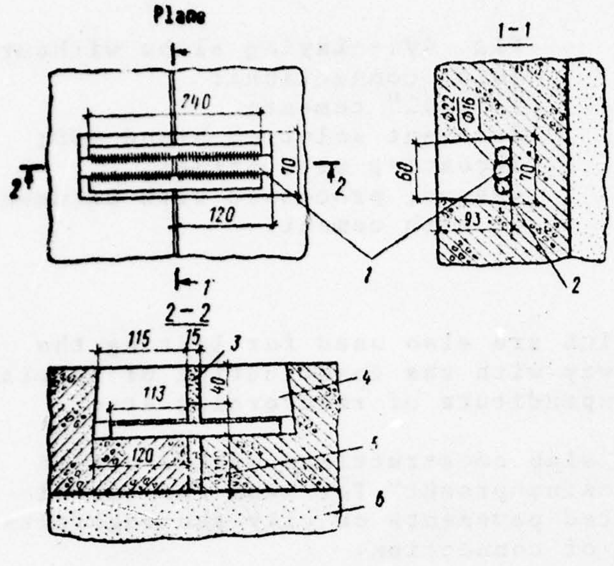


Fig. 50.--Connection of the slabs by welding the working reinforcement outlets:

1-working reinforcement;
2-electrical welding;
3-"Izol" cement;
4-filling with an epoxide compound;
5-cement solution of brand 400;
6-sand, processed with bitumen.

Prestressing in the indicated designs provides the possibility of obtaining a slab with considerable length and width from the individual prefabricated elements of small dimensions and makes it possible to create stress not only in the junctions, but in the slabs themselves. The basic shortcoming of these designs is the complex technology of manufacturing the slabs (the necessary of leaving channels for letting through a stressed reinforcement), and also the complexity of installing the pavement (stressing the reinforcement with the aid of jacks, injection of the channels with solution, etc).

The scientific workers of the SoyuzDorNII proposed a prefabricated pavement made of slabs having multiple hollow spaces with connection of them by means of stressed joining. In this case, the slabs are connected to each other by means or rod or bundled reinforcements, passed through the hollow spaces (in longitudinal direction) or special grooves on the butt end grains of the slabs (in transverse direction). 4-5 slabs are connected simultaneously along the traffic lane. The number of slabs transverse to the passing lane is taken as a function of its width. The reinforcement let through all the slabs is stressed with the aid of hydraulic jacks. Another version of the given design is a variation of the prefabricated pavement with a self-stressed transverse reinforcement in the form of a thin sheet of steel or steel lines placed in grooved recesses of the slabs having multiple hollow spaces. However, because of the complexity of the installation technology, the great amount of work in preventing technological fractures and injection of the channels (hollow spaces) as well as the low useful quality, these and other designs of stressed connections have not been widely used in road construction.

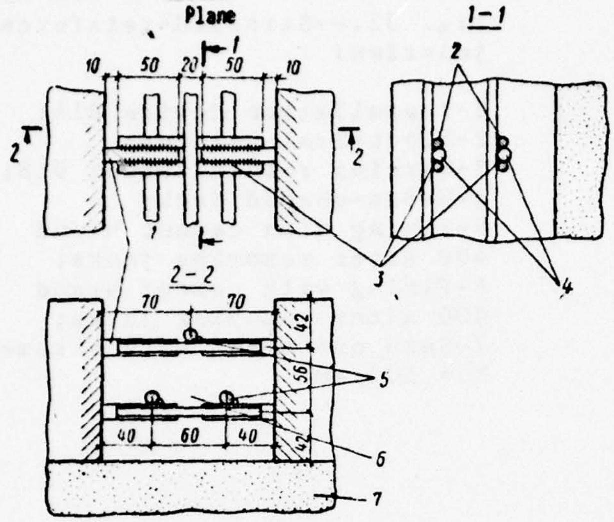


Fig. 51.--Connection of the slabs according to the type "reinforcing beam"

1-4-working reinforcement Ø12
2-installation devices Ø 10;
3-electrical welding;
5-additional installation reinforcement Ø 10;
6-Fixing with concrete brand 400;
7-sand, processed with bitumen;
h = 100 mm.

From the experience of constructing hydrotechnical buildings (reinforcement of the wavy inclinations), a design of a junction is known which is stressed in installation of the pavement with the aid of two-dimensional jacks. In this design, the ends of the working reinforcements (rods or high-strength reinforcing wire) of two contiguous slabs are joined to each other by different methods, and then, placing the two-dimensional jack in the grooves, the slabs are pushed apart, temporary brace struts are installed and, after removing the jacks, the junctions are filled with concrete.

To obtain the necessary degree of concrete compression, the outlet of the reinforcement (especially of the rod) in the given design must have sufficient length, since in case of a short length, their lengthening when pushing the slabs apart is insignificant and the compression of the junction will be insignificant. Long, free outlets increase the width of the junctions, and consequently the amount of work in their connection.

In the majority of junction variations with outlets of wire reinforcements, it is almost impossible to achieve uniform length of all the outlets. When connecting them with dowels, the individual outlets turn out to be weakly stressed when moving the slabs apart, others with prestressing undergo great stresses and sometimes fracture. This also leads to insufficient compression of the junction.

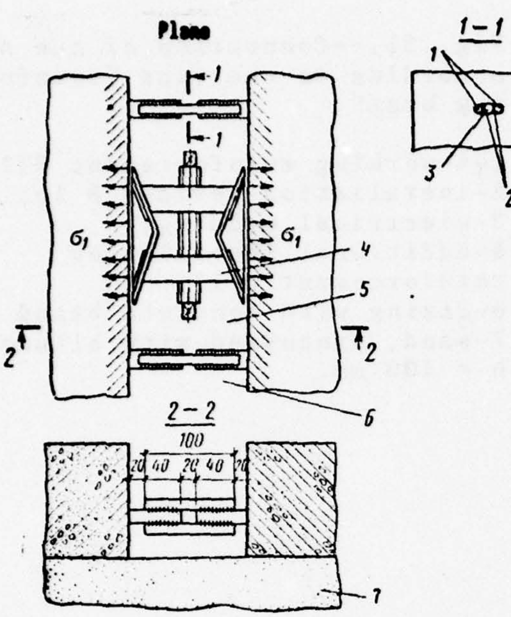


Fig. 52.--Stressed-reinforced junction:

1-Installation device Ø14;
2-Electrical welding;
3-Working reinforcement Ø18;
4-Wedge-shaped jack;
5-Fixing with cement brand 400 after removing jacks;
6-Fixing with cement brand 800 after removing jacks;
7-Sand processed with bitumen, h = 100 mm.

In working out the designs of prestressed slabs for experimental construction by the project institute "Mosinzhproekt" in some pavement designs it was proposed to accomplish the stressing of the junctions with the aid of wedge-shaped jacks. The design of such a junction is shown in Fig. 52.

The scientific workers of the all-union correspondence engineering-constructional institute worked out a design for a prestressed junction with the use of flat jacks for stressing and with the use of a solution injection device*. The construction scheme of a prestressed junction of given construction is shown in Fig. 53. Its distinctive special feature is that an element of a flat turned steel pipe is used here as a flat jack, which looks like a flat strip, consisting of two steel bands (width 180-200 mm, thickness 1-1.5 mm), welded along the edges. After laying the slabs in the pavement and welding of the insertion component parts, the element of the pipe is inserted in the gap between the slabs, equal to 15-20 mm.

*Patent No. 154556

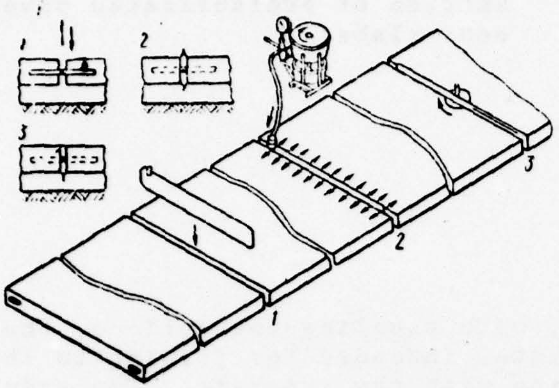


Fig. 53.--Installation scheme of a prestressed junction:

1-Installation of the laying component part from a flat-turned pipe; 2-injection of the solution; 3-Cross section of the protruding part of a laying component.

The solution is fed under pressure through the flexible hose and the nozzle from the solution installation into the element of the pipe. The pressure from the tube walls is transmitted onto the butt end grains of the slabs with a single force at all points. The butt end grains of the slabs along the junction undergo preliminary stress, the value of which may be obtained in wide limits. After the solution has finished hardening, the part of the host projecting over the surface of the slabs is cut off with an abrasive.

The element of the flat-turned pipe and the solution, with the aid of which pressure is created in the tube and stress is created in the junction, fulfill two tasks: initially, as a jack, they create stress in the junction, and then, after hardening of the solution and cutting off of the projection part, it serves as material for filling the junction between the welded laying elements. After finishing, a solid junction is obtained in which the edges of the slabs and of the solution are limited by two sides of densely compressed sheet steel protecting them from damage when an automobile wheel runs over them. With such a method of joining the slabs, we preclude the possibility sagging and bending of the slabs according to height; with a correct technology of slab manufacture and of joint stressing we obtain a smooth driving highway surface; a highly stable solution, tightly adjacent to the walls of the flat tube protects the base from surface moisture.

The basic shortcoming of jucntions with welded connections is the use of electrical welding, which complicates the use of such connections in prefabricated-sectional pavements and with the substitution of individual slabs in the pavements of the fundamental type in the case of their wear with forced opening of the road surfacing.

The indicated shortcomings may be removed with the use of threaded connections (connecting pieces and bolts) for stressing the junctions, also worked out at the VZISI.* Such junction connections were used with the construction of prefabricated pavements made of large-dimensioned prestressed reinforced concrete slabs in the city of Dnepropetrovske.

*Patent No. 193563, 1967

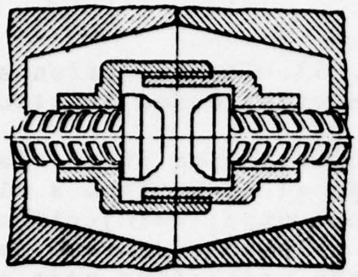


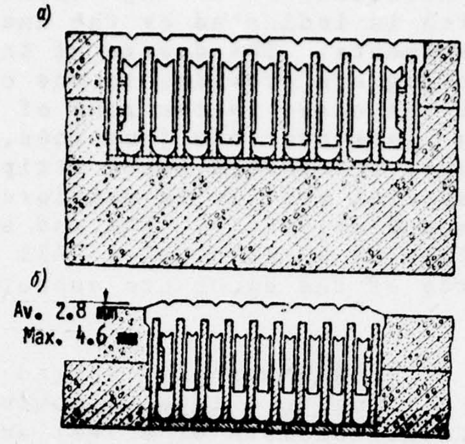
Fig. 54.--Coupling threaded connection of prefabricated pavement slabs.

In prestressed slabs (Fig. 54), with coupling connections, the end parts of the working reinforcements, indended for joining to the necessary length, do not have coupling with the concrete. The ends of the reinforcements may be insulated with a first coating of a special cement or placed in metal, rubber, plastic or cardboard tubes. Special recesses are made for the possibility of connecting the rod reinforcements of two contiguous slabs with each other with the aid of connecting pieces. The recesses are placed on the butt end grains of the slabs. Moreover, the ends of the reinforcements situated in the recesses do not reach up to the plane of the butt end grains of the slabs by 0.5-1.0 cm. After the slabs are made, connecting pieces are placed on the projecting ends of the reinforcement (sleeve or another type) and thrust washers are welded on.

As a result of tightening the connecting pieces (screwing on of the sleeves or of the tightening bolts), the tensile forces of a calculated value are transmitted to the rods. As a result of tightening the rods of the junction reinforcement,the compressive forces are transmitted to the cement, the value of which may be determined according to the forces in the reinforcement (with consideration of all losses). Thus, preliminary stress is created in the concrete of the slabs (in the zone of the junction). The compression value of the concrete in the zone of the junction will be determined by the value of the calculated load, the design of the slabs and of the threaded connection. The number of junction rods and their diameter is determined by the value of the preliminary stress in the concrete of the slabs.

The basic advantage of prestressing the junctions with the aid of threaded connections, compared with welded ones, is the rapidity of installing the pavement, and necessary cases (repair of destroyed slabs, repair or laying of underground lines, etc) and the possibility of its rapid dismantling. Threaded connections for the construction of temporary (prefabricated-sectional) constructed roads should be considered especially prospective. Such connections in the designs of slabs of prefabricated-sectional pavements guarantees their multiple circulation.

In temporary pavements, the slabs may be laid "dry", i.e. without preparation or with laying of butts between the slabs with a special elastic foundation.



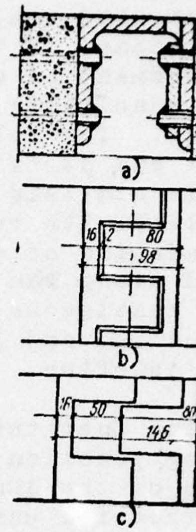


Fig. 55.--Filling the junctions of the widening of prestressed prefabricated-monolith pavements with rubber, reinforced steel strips: a-design of the junction; b-junction after temperature compression deformation.

Fig. 56.--Junction of the widening according to the movable comb type: a-cross section; b-position of the junction maximum calculated temperature; b-position of the junction with maximum cooling in winter.

In pavements of the same principal type, small gaps (5-6 mm) must be placed between the slabs before stressing the junction at installation, which must be filled with a plastic, cement-sand solution, prepared on the basis of ordinary or fast-drying cement. Pouring the solution into the junction provides the possibility of guaranteeing its water impermeability, and also makes it possible to remove individual unevennesses and defects (puncturing) of the concrete in the butt end grains of the slabs which appear in the process of their manufacture and transportation. Elimination of the unevennesses facilitates a more correct distribution of the compressive forces in the concrete of the slabs.

In pavements of the principal type, cementing of the slabs may be accomplished simultaneously with stressing. With the use of cementing and of prestressing of the junction places, full strength of any cross section of the joined slabs is not only achieved, but water impermeability as well.

The best known and approved cements for a rigid connection of concrete and reinforced concrete articles with each other is cement prepared on the basis of epoxide resin, and also cement glue, having high strength characteristics and adhesion properties.

In prefabricated-monolithic pavements of automobile highways with rigid junctions, it is necessary to arrange expansion joints, the placement of which is indicated by the installation of such joints in monolithic pavements. The design of these joints may be different. The following are provided in one of the variations: the butt end parts of the slabs in the zone of the expansion joints are laid on slabs over the junctions, and the junction is filled with rubber, reinforced steel strips (Fig. 55). The rubber foundation of a speeial profile is reinforced with special strips arranged along the expansion joints. The end strips are connected with contiguous slabs by steel dowels. All designs of the junction and the end parts of the slabs are supported on the slab under the junction.

The planning institute of "Mosinzhproekt" worked out a design for the widening junction according to a type of moving comb (Fig. 56). One of the junctions consists of a left and a right comb, cut out from the unequal-sided angles with a cross section 125x80x12 mm. The combs are fastened to the slab by welding the working reinforcement directly with the left comb and with overlapping of the right comb. The use of overlapping, which is directly welded with the working reinforcement, clamping the comb, provides the possibility of moving it into several points along the junction, which simplfies laying the slabs in the pavement. Other variations of designing the widening junctions are also possible.

Chapter II

Bases for the Construction and Calculation of Prefabricated Highway Pavements

§8. Basic Assumptions and Recommendations in the Design of Prefabricated Pavement Slabs

The following requirements are governing in the design of slabs for prefabricated pavements and bases:

after laying and joining, the slabs must form a stable and smooth pavement (base), not yielding to similar monolithic designs in its exploitational-transport characteristics;

the consumption of material per unit of area must be as small as possible;

the installation work in constructing the prefabricated pavement must be uncomplicated, carried out with available equipment and must provide rapidity of construction time;

the designs of the slabs must not cause technological difficulties with their manufacture;

the cost per unit of area of the prefabricated pavement must be minimal.

The slab designs to a large measure depend also on the nature of the used materials, the presence of technological equipment for their manufacture and laying, and also other conditions, considering the special features of the concrete constructional objects.

The search for optimum constructional solutions and a multitude of conditions for the use of prefabricated pavements led to the fact that, at the present time, despite the relatively small volumes of their construction, a considerable number of different slab designs are known. There are slab designs of quite different shapes: rectangular, square, hexagonal, cruciform, round, etc. The area of the slabs fluctuates within wide areas: from 0.05 to 20.0-40.0 m^2 and more. The slabs have different thicknesses, different forms of joint connections and supporting surfaces. The upper plane of the slab is made flat. Sometimes, especially on sidewalk slabs, they construct an artificially roughened surface. The lower (supporting) surface in the series of constructions has a figured or irregularly shaped contour: concave, ribbed, caisson type etc.

The great variety of constructional forms, and in particular with a complex contour of the lower surface is explained by the striving to provide macimum stability of the slabs under traffic and their tight contact with the base.

In each case, the optimum designs of the slabs are determined on the basis of a complex technical and economical analysis of different variables with consideration of the presence of materials and their properties, the technology of manufacture, transportation, installation, requirements for laying down an underlayer, and also the conditions and consumptions of the future exploitational period.

Some general considerations in selecting the dimensions and the material for slabs of prefabricated pavements and bases are given below, developed in the practice of construction and planning.

In order to provide the best conditions for automobile traffic, it is necessary to strive for reducing the specific (per unit of surface) distance of the junctions (especially the transverse ones) on the pavement. This requirement coincides with the requirement of economic order in the area of exploitation of the prefabricated pavements. Yearly consumptions in content and the repair of prefabricated pavements are reduced with a reduction in spacing the junctions.

The specific spacing of the junctions is reduced with an increase in the dimensions of the slabs in the plane. Consequently, starting with requirements of a transport and exploitational character, it is necessary to assemble prefabricated pavements from slabs of as large as possible dimensions in the plane. The use of large-dimensioned slabs also reduces the number of junctions required per square unit of prefabricated pavement. Since the cost of contemporary junction constructions (threaded, prestressed, etc.) is considerable, then then reducing their number reduces the general constructional cost of prefabricated pavements.

For the installation of prefabricated pavements on main automobile roads, city streets and square, from the conditions of reducing the number of junctions and providing high degrees of smoothness, an attempt is made usually to use reinforced concrete slabs with large dimensions. In a series of cases, the slab dimensions of prefabricated reinforced concrete pavements are close to the dimensions of slabs for monolithic pavements. The use of prestressed reinforced concrete provides the greatest effect in this regard, making it possible to greatly increase the dimensions of the slabs in the plane, while at the same time reducing their thickness.

The introduction of road surfaces of large dimensioned slabs into construction to some degree restrains the insufficient power of the crane equipment available to road organization and sustains the considerable technological difficulty in providing tight and uniform contact between the base and the large dimensioned slabs.

In addition to calculating the slabs for stresses emerging under the effect of temporary load, when determining the limit dimensions of the slabs and their weight, it is also necessary to check their stress stability, effective in the installation process. The larger the dimensions of the slabs in the plane, the greater the so-called "installation" stresses emerging in them. In the majority of cases, for reinforced concrete slabs these stresses do not exceed the stresses from the effect of temporary loads. However, in indi-divudl cases, with unsuccessful design of the clamping devices, they may be great.

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Just like the large dimensioned ones, slabs with relatively small dimensions are frequently used, especially on roads and streets with a low traffic frequency. So, in a series of cities, they used hexagonal reinforced concrete slabs for street pavements with an area of 3.50 m^2, also using concrete slabs with an area of 1.0-3.0 m^2.

The dimensions of the slabs to a considerable degree depend on the quality of the used materials. At the present time, slabs with prestressed reinforced concrete have the largest dimensions in the plane. Slabs made of silicate concrete and lithim slag also transmit large bending moments without destruction. But their dimensions are usually large, which is primarily explained by the conditions of their manufacture (in a series of cases, the dimensions of silicate-concrete slabs are limited by the overall dimensions of the autoclave equipment used).

In the past few years, large autoclave equipment has appeared making it possible to manufacture silicate concrete slabs of large dimensions. However, the number of such pieces of equipment is still insufficient.

The casting of slag slabs is still in a stage of assimilation. As yet, the designs of these slabs are like the concrete ones.

Slabs made of bitumen-mineral mixtures have insufficient rigidity and when they have large dimensions, they deform during installation. Thus, as a rule, they are smaller than reinforced concrete slabs. Their area in the plane does not exceed 3-6 m^2.

The dimensions of the metallic slabs and of the wooden housings are not limited by the stresses during installation work and are determined mainly by the requirements for the pavement, the transportation conditions and the possibilities of the equipment used for laying.

In the designs of rigid slabs of prefabricated pavements, in the majority of cases, provision is made for joint installation, providing transmission of the temporary load from one slab to another (welded, bolt, etc.). Such designs improve the working conditions of the slabs and to a certain degree make it possible to reduce their thickness or to reduce the content of the reinforcements. However, in the practice of road construction, there are occasions of laying prefabricated pavements and, especially often, bases, without joint installation. The advantage of such designs is simplifving the technology of their manufacture and laying, and correspondingly reducing the cost of these works. At the same time, the thickness of such slabs and the consumption of materials in their manufacture are usually greater than in constructions with joint installation, although providing redistribution of the load between contiguous slabs.

Joint connections are not made in slabs from inflexible materials (bitumen-mineral, asphalt-concrete).

Slabs for temporary roads have relatively small dimensions. The basic conditions for their design are considered simplicity and rapidity of installation. The width of the slabs for gauge pavements

is usually considered equal to 1 m, the length of the order of 2-4, less frequently 6 m.

For sidewalk coverings and pavements of park roads they use slabs of small dimensions with an area of 0.5-022 m^2 and less. The decisive requirment for their planning in the majority of cases is the possibility of using small mechanization means for their installation. Thanks to the low temporary load on the slabs of sidewalks and road, there is not the necessity to absolutely guarantee the transmission of forces from one slab to another. Thus, as a rule, the side grains of these slabs have simple contours, without any joint installations.

Planning the slabs of prefabricated pavements and bases is usually accomplished in several stages. First, based on the data of the technical literature and of industrial experience, the design of the slabs is approximately decided on. Then, by means of calculation, we specify its dimensions and form, after which we work out the final design sketches. Moreover, the method of variational planning is used, i.e. several variations of the slabs are worked out, then the best of them is selected by means of technical-economical comparisons.

In the process of working out slab designs, the indications of the prevailing standard documents are governing, as well as the technical, economic and technological requirements worked out in the practice of planning and constructing prefabricated road surfaces. A part of these requirements is general for all slabs, independent of their function and material. The other part is changed depending on the type of materials used for manufacturing the slabs, or the special special features of their function.

The shape of the slab in the plane and its basie dimensions must be correlated with the dimensions (width) of the travelled part. The width of the slab must be a multiple of the width of the travelled part. Slabs with a large dimension of the width and length are disposed with the long side along the axis of the road. The purpose of such a disposition of the slabs is to reduce the number of transverse junctions on the pavement, creating jolts with the movement of automobiles. The number of longitudinal joints is not of essential importance, since only diagonal intersecting of their wheels is possible with the movement of automobiles without perceptible impacts.

A quadrate form of the slabs is not optimum under the effect of a moving load, according to the working conditions. Increased (compared with the central part) stresses emerge in the corners of the slabs, for the perception of which constructional reinforcement is required in these zones of the slab. Other conditions being equal, hexagonal and round slabs work much better under load.

However, slabs of such shapes are poorly inscribed in the limits of the narrow ribbon of the travelled part with rectilinear edges. For laying down along the edges, it is necessary to make special semi-slabs both hexagonal and round. From this point of view, their use may be practical only in laying on squares or streets with a narrow travelled part (in the case of multi-lane traffic).

But with the use of round slabs, in all cases about 20% of the surface of the pavement is not closed with prefabricated elements and it requires additional laying down of various mixtures or crushed stone materials.

It is also necessary to check the slab designs for the appropriateness of technical requirements: convenience of manufacture, the possibility of using available crane equipment, or crane equippment which is planned to be obtained for the loading-reloading and installation work, the conformity of the weight of the slabs to actually possible transport means, etc.

So, for economy of the material and to reduce the weight of the slabs, and also to provide their better contact with the base in some designs, a complex contour of the lower surface is provided: in the form of gently sloping arches, several series of caissons, networks of through apertures, etc. The material is actually used more advantageously in such slabs, however, their manufacture, and frequently their mounting, are greatly complicated, thus the use of complex designs of slabs must be carefully based. Usually it is justified only with great economy of the material with great increase in the qualitative factors of the entire prefabricated pavement.

The weight of an individual slab and, consequently, its dimensions (length, width and thickness) must not exceed the lifting capacity of the lifting-reloading and laying machines designated to be used. When laying prefabricated pavements of sidewalks and park roads, in some cases, in connection with insufficient mechanization means, the possibility of manual laying is provided and the weight of the used slabs is limited correspondingly.

The weight of one slab must also be a multiple of or equal to the lifting capacity of the transporting units (automobile or trailer). This circumstance must be taken into account when planning the slabs, especially ones of small dimensions; in the opposite case, a situation may emerge when the fleet of existing automobiles will be used to transport the slabs with a low coefficient of tonnage use, and the cost of transporting is unjustifiably increased. Meanwhile, the cost of the transporting work constitutes a considerable part in the general cost of constructing highways (up to 25-35%) and its irrational increase must not be permitted.

The thicknesses of the slabs are determined mathematically. They fluctuate within wide ranges. The thicknesses of the slabs of prefabricated road pavements and bases change on the average from 10-20 cm, of sidewalks from 3-6 cm. The thickness of the slab, and also the dimensions of its individual parts, especially in the case of complex design solutions (angles, edge thickenings, joint constructions, etc), are designed with consideration of experience in completing similar designs and the properties of the used materials. The different designs of reinforced concrete are studied to a considerable degree. This makes it possible to work out a series of recommendations in designing road, reinforced concrete slabs and above all on the disposition of reinforcements in them.

A layer of concrete in the lower zone of the slabs is used, not less than 20 mm, to protect the reinforcements from corrosion; a protective layer of concrete is used, not less than 30 mm [32] on the surface of the layer, taking into account their possible wear in the process of exploitation. The thickness of the protective layer of concrete for clamps and for transverse rods of welded frameworks in the ribs must amount to not less than 15 mm, and for the feinforcements disposed in the slabs, not less than 10 mm.

The ends of the longitudinal working rods of the reinforcement, not welded to the anchoring component parts, must be separated from the butt end of the slab not more than 5 mm. The distances in the clearance between the rods according to the height and width of the cross section are designated with consideration of convenience of laying and condensation of the concrete mixture. The distances in the clearance between the individual longitudinal rods, and also between the rods of the neighboring flat, welded frameworks are composed:

a) if the rods, with concreting, occupy a horizontal position not less than the diameter of the rods and not less: for the lower reinforcement 25 mm and for the upper reinforcement 30 mm;

b) with concreting, if the rods occupy a vertical position not less than 50 mm

Anchoring of the reinforcement of periodical profile is accomplished without hooks. The smooth reinforcing rods used in welded frameworks and in welded screens, also are made without hooks, moreover, transverse anchoring rods must be welded to each longitudinal rod along the length.

The butt end and edge zones of the irregularly-shaped and continuous slabs are reinforced according to mathematical and design considerations with a somewhat larger number of reinforcements than the central zones. To anchor the ends of the prestressed longitudinal working reinforcement, wide use is made of spirals made of cold-drawn wires with a diameter of 3 mm, making it possible to accomplish reliable anchoring of the reinforcement in a section not larger than 10-12 cm.

The anchoring, transverse rods in welded frameworks are recommended to be welded with contact, spot welding. To connect the butts of reinforcing rods under factory conditions, it is recommended to use a contact junction weld for reinforcing steels of classes A-I, A-II, A-III, with a diameter of 10-40 mm.

When designing ribbed and cellular slabs of unstressed reinforced concrete, their thickness is usually designated in the limits of 16-18 cm, prestressed ones in the limit of 12-14 cm. The minimum thickness of the ribs along the bottom constitutes not less than one diameter of a reinforcement combined with a double thickness of the protective layer of concrete. The thickness of the upper loading platform is designated on the basis of the smallest dimension of the fraction of the large filler, i.e. not less than 40-50 mm. In the transverse cross section of the cellular slabs, the distance between

the ribs (diaphragms), must be such that reinforcing of the parts of the slab between the diaphragms is not required: the width of the concrete in the lower zone must constitute not less than 40% of the width of the transverse cross section of the slab. In the longitudinal cross section, the distances between the diaphragms is designated according to the disposition of the transverse reinforcement.

Table 7

Steel brand	Diameter of the slab rod, mm	Standard stress from gravity of the slab exerted on one eyelet, kg
Reinforcing steel	6	100
round smooth	8	300
profile class	10	700
A-I according to GOST 5781-	14	1500
61, brand VM ST3sp	16	2000
and VK ST3sp	18	2500
according to GOST 380-60	20	3100
	22	3800

Note: 1. With the use for lifting of an element of four installation loops, standard load from gravity of the element considered distributed on three loops. 2. In these cases, when absence of bend of the loop is guaranteed (mounting with the aid of crosspieces, it is permitted to increase the standard load on the loop 1.5 times.

The upper and lower longitudinal and lower transverse reinforcement in such slabs is designated according to calculation. The area of the cross section of the distributed reinforcement in girder slabs must amount to not less than 10% of the area of the cross section of the working reinforcement put in the place of the larger bending moment.

In ribs with a height of more than 150 mm, the transverse rods, if they are not required according to calculation, must be placed at the ends of the element on the part not less than 1/4 the length of the rib. The upper and lower reinforcing screens are usually joined in the framework with the aid of clamps or welded to the rods of the longitudinal reinforcement.

The thickness of the protective layer of concrete for the working reinforcement is assumed:

in the walls with a thickness up to 100 mm including not less than 10 mm;

in the walls with a thickness of more than 100 mm, and also in beams and ribs with a height up to 250 mm at $d_{ar} <$ mm not less than 15 mm.

The installation of mounting eyelets is provided for in many slab designs for grasping them when being lifted with a crane. The rod diameters for the loops is recommended according to Table 7 depending on the standard load exerted on the eyelet.

Anchoring of the eyelet is accomplished letting the ends of the eyelet into the concrete of the prefabricated element at length l not less than 30 d (d is the diameter of the eyelet shaft).

When manufacturing the reinforced slabs of silicate concrete, basic recommendations are made for them, worked out for ordinary reinforced concrete. Some authors, taking into account the increased (compared with compact cement concrete) porosity of the silicate concrete, recommend increasing the thickness of the protective layers to 5-10 mm for the purpose of better protecting the reinforcements from corrosion.

When reinforcing bitumen-mineral slabs and reinforced bases with wood frameworks, the thickness of the protective layer is recommended as 40 mm. The metallic mounting eyelets on such slabs are installed at a distance of for example 1/6 l from the butt ends of the slab and 1/5 b from the edge of the slabs (l-length of the slab, b is its width).

The eyelets are fastened onto the upper plant of the wooden framework. When calculating the bitumen-mineral slabs, it is necessary to check the installation stresses emerging in the process of laying them. In connection with insufficient strength at low temperatures, bitumen-mineral slabs usually have dimensions in the plane of not more than 1.75x3.00 m. More frequently, their thickness is encountered as 14-20 cm.

The basic part of planning the slabs of prefabricated pavements is their calculation. The Stability and longevity of prefabricated pavements are determined primarily by the character and special features of their stressed-deformation state, emerging as a result of the total of all the external effects. The calculation of the pavements must with maximum approximation take into account all the working conditions of the slabs and the emergence of stresses in them and, on the one hand, guarantee the most economical disposition of the slab material (minimum thickness, minimum expenditure of reinforcements) and from the other side its efficiency in the course of a given period of time.

The development of mechanics of road surfaces is the process of mutual development of a calculation for rigid and flexible road surfaces. At the initial stage to rigid road surfaces they used the theory of calculating the foundations for the static effect of load. In the works of domestic and foreign scholars (Goldbeck, Older, Westergard, Bredbyuri, V.F. Babkov, N.N. Ivanov, I.A. Mednikov, A.S. Smirnov, S.V. Konovalov, G.I. Glushkov, B.S. Raev-Bogoslovskii, I.I. Cherkasov, B.I. Demin, et al) it was shown that the basic relationships in the calculation of foundations, with some limitations and with experimentally obtained limits, are used for calculation of rigid highway pavements. However, the essential shortcomings of such an approach to the calculation and its temporary character were noted already in these studies.

In a series of subsequent studies, especially in the course of experiments set up in the USA, it was found that the repetition of the effects of automobile loads exerts a very important influence on the work of rigid pavements, to a large extent determining the efficiency of rigid road surfaces.

The theory for the calculation of flexible road surfaces was worked out in the USSR under the guidance of Prof. N.N. Ivanov. It was based on the principle of taking into account the influence of the repetition of the effect of automobile loads and introducing a multilayered system of equivalent deformation.

Subsequently, solutions to the theory of elasticity appeared in the USSR and abroad, presently used for calculating a double-layered and multilayered systems (D.M. Burmeister, B.I. Kogan, Johns, M.B. Korsunskii et al.), and also proposals for calculating the possible shifts in disconnected and slightly connected layers of road surfaces (Wilson, Williams, V.D. Kazarnovskii, A.M. Krivskii et al). The latter proposal in the practice of calculating flexible road surfaces still has not been finally expressed.

At the present time, these questions are posed applicable to rigid road surfaces and find some solutions in the studies of the SoyuzDorNII* and MADI**.

In planning the designs of prefabricateddpavements, it is necessary to orient ourselves to the use of the theory of calculating slabs on an elastic semi-space, worked out basically by soviet specialists.

Depending on the designation of the pavement (principal or temporary) it is determined in which stage (elastic or plastic) the base under the pavement will bperate with a calculated load. This is necessary for pavements of automobile roads of the permanent type so that only elastic deformations will emerge in all designs of the road surfaces in combination with the ground road bed under load. Plastic deformations may also be permitted in strictly limited bounds in the bases of temporary pavements.

The calculation of prefabricated pavements of the rigid type has been theoretically substantiated and worked out practically in sufficient detail. The use of existing methods makes it possible at the present time to determined the stresses emerging in the slabs with sufficient accuracy and respectively the necessary design dimensions. The problems of calculating and designing the bases under these pavements have been worked out to a lesser degree. Methods for calculating the bitumen-mineral and asphalt-concrete slabs have also been insufficiently worked out. Considerable difficulties emerge in attempts at an accurate calculation of the rigidity of these slabs, which changes depending on the temperature of the ambient air. At the present time, the calculation of the rigidity of pavements and bases made of bitumen-mineral and asphalt concrete slabs is led according to the method of SoyuzDorNii or MADI (prof. N.N. Ivanov), including ordinary road surfaces of the flexible or semi-flexible type. The requirements for the design of these slabs are established according to the installation conditions mostly according to the data of practical experience.

9. Theoretical Prerequisites for Calculating the Slabs of Prefabricated Pavements

The determination of the calculated forces in prefabricated, inflexible pavements of automobile roads is based on the theoretical calculation of the designs on an elastic base.

*SoyuzDorNII. Proposals for calculating and designing cement-concrete slabs on bases of different types. Balashixa, Moscow, 1968.
**Ivanov, N.N., Koganzon, M.S., Konovalov, S.B. New Methodical Bases for calculating inflexible road surfaces with consideration of the repeated effect of loads. M., "High School", 1969.

The calculation of road slabs with large dimensions (for example 3.75 and 5), i.e. with the width of the slab for example equal to the width of the travelled strip, with the disposition of the load in the center of the slab is usually carried out according to formulas for calculating infinite slabs. Slabs are considered infinite in a mathematical sense, the finite dimensions of which do not influence the value of the small bending moment, emerging with its loading with a vertical load in the central zone.

One of the first solutions to the problem concerning the bend of an infinite slab on an elastic area with loading with a vertical load, distributed over the area of a circle, was proposed in 1939 by doctoral science candidate O.Ya. Shexter. Subsequently, doctoral science candidate B.V. Babkov showed the applicability of this solution to the calculation of inflexible road surfaces.

According to the method of O.Ya. Shexter, the values of the large bending moment M and the large deflection W of the slab, emerging under the effect of load P, are determined by the following equations:

$$M = P(1 + \mu)\bar{U} \quad (1)$$

$$W = \bar{W} \frac{\alpha R}{E_0} \quad (2)$$

where P is the general value of load, kg; μ is the Poisson coefficient of the slab material; a-is the parameter of slab rigidity, cm^{-1}; E_0 is the modulus of elasticity of the base material at compression without the possibility of its side expansion, kg/cm^2; $\bar{U}$ is the dimensionless value of the maximum bending moment under the denter of load application, used according to the table, as a function of the value aR (see further on); $\bar{W}$ is the dimensionless value of maximum deflection of the slab under the center of load application, equal to 0.385; R is the radius of the circle along the area of which load P is transmitted to the pavement, cm.

The parameter for the rigidity a of the slab of rectangular cross section is determined according to the formula:

$$a = 1/h \sqrt[3]{6E'_0(1-\mu^2)/E(1-\mu_0^2)} = 1/h \sqrt[3]{6E_0/e} \quad (3)$$

where h is the thickness of the slab, cm; E', μ and E_0', μ_0 are the modulus of elasticity and the Poisson coefficient respectively, of the slab material and of the base material.

The elasticity moduli of the slab materials and the materials of the base at compression without the possibility of side expansion E and E_0 are respectively equal to

$$E = E'/1-\mu^2 \text{ and } E_0 = E'_0/1-\mu_0^2$$

The value of the circle radius, equal in area to the impression of the wheel of a calculated automobile, is determined according to the expressions:

$$R=\sqrt{\frac{P}{\pi p}}. \quad (4)$$

where p is the specific calculated pressure of the automobile wheel on the pavement, equal to the specific pressure of the air in the tires, multiplied by the coefficient taking into account the rigidity of the tire itself (usually this coefficient is assumed to be equal to 1.1), kg/cm^2.

Values of the Dimensionless Bending Moment $\bar{U}$ in Eq. (1)

With $aR=0$	$U=\infty$
» $aR=0,05$	0,287
» $aR=0,10$	0,232
» $aR=0,20$	0,178
» $aR=0,30$	0,147
» $aR=0,40$	0,124
» $aR=0,60$	0,093

To determine the maximum bending moment (under the center of the load) in a dimensionless slab on an elastic semi-space, loaded equally over the area of the circuel, it is possible to use the same formula proposed by doctoral science candidate M.I. Gorbunovim Pasadovim [13] which has the form:

$$M=P(0,0592-0,214\lg aR) \quad (5)$$

and gives results practically coinciding with the solution of O.Ya. Shexter (formula 1) with $aR \leq 0.6$.

The value of the bending moment may be determined at other points of the infinite slab according to the formula

$$M = \tilde{M}P$$

where M is the dimensionless value of the bending moment taken according to Table 8 as a function of the given coordinates ($\eta\xi$) of the point in which the value of the moment is determined.

The given coordinates η and ξ are calculated according to the following formulas:

$$\eta=ax=\frac{x}{L};\ \xi=ay=\frac{y}{L}.$$

where x and y are the actual coordinates of the point in which the value of the moment is determined; the center of the load application is taken for the beginning of the coordinates; a--is the parameter of slab rigidity (3), cm^{-1}; L is the radius of slab rigidity (cm) determined according to the formula:

$$L=\frac{1}{a}=h\sqrt[3]{\frac{E}{6E_0}}. \quad (7)$$

Table 8

η (ξ)	ξ (η) 0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
0,0	∞	0,129	0,068	0,036	0,016	0,004	−0,005	−0,011	−0,014	−0,015	−0,017
0,2	0,194	0,133	0,072	0,039	0,018	0,005	−0,003	−0,010	−0,013	−0,014	−0,017
0,4	0,132	0,110	0,071	0,042	0,021	0,006	−0,002	−0,008	−0,011	−0,013	−0,015
0,6	0,096	0,087	0,063	0,042	0,023	0,009	0,001	−0,006	−0,009	−0,012	−0,013
0,8	0,074	0,068	0,054	0,039	0,023	0,011	0,002	−0,004	−0,007	−0,010	−0,012
1,0	0,057	0,054	0,044	0,034	0,022	0,012	0,004	−0,001	−0,005	−0,008	−0,011
1,2	0,045	0,042	0,037	0,023	0,020	0,011	0,006	0,000	−0,004	−0,007	−0,009
1,4	0,035	0,034	0,030	0,023	0,017	0,011	0,006	0,001	−0,003	−0,006	−0,007
1,6	0,028	0,027	0,024	0,020	0,015	0,010	0,005	0,002	−0,002	−0,004	−0,006
1,8	0,022	0,021	0,019	0,017	0,013	0,008	0,005	0,002	−0,001	−0,002	−0,004
2,0	0,018	0,018	0,015	0,014	0,011	0,007	0,004	0,003	0,000	−0,002	−0,003

With the aid of Table 8, it is possible to determine the bending moment in an infinite slab according to two mutually perpendicular directions M_x and M_y; moreover, in order to determine the M_y for the graphs of table 8, it is necessary to substitute the coordinate η on the coordinate ξ and correspondingly for the columns of table 8, the coordinate ξ must be substituted on coordinate η.

If the slab has a non-continuous (irregularly shaped) transverse cross section, then the parameter of rigidity of the slab is determined according to the formula

$$a=\sqrt[3]{\frac{E_0'}{2D(1-\mu_0^2)}}=\sqrt[3]{\frac{E_0}{2D}}, \qquad (8)$$

where D is the linear slab rigidity, kgcm, relative to one unit of cross section width.

The rigidity D of the irregularly-shaped cross section of the slab, operating under load without the formation and the detection of cracks (for example, slabs of pre-stressed reinforced concrete), is assumed to be equal to its cylindrical rigidity:

$$D=\frac{E'I}{b(1-\mu^2)}=\frac{EI}{b}, \qquad (9)$$

where I is the moment of inertia of the slab cross section relative to its neutral axis, cm^4; b is the width of the cross section, cm.

For a slab of continuous (rectangular) cross section with height h

$$D=\frac{E'h^3}{12(1-\mu^2)}=\frac{Eh^3}{12}. \qquad (10)$$

In slabs operating under load with the formation and discovery of cracks (reinforced concrete slabs), instead of the cylindrical rigidity D we take the linear rigidity B_π determined with consideration of the presence of cracks according to the formulas of Prof. V.I. Murasheva (see formula 48). In this case, the parameter of rigidity of the slab a is determined according to the formula

$$a=\sqrt[3]{\frac{E_0'}{2B_\pi(1-\mu_0^2)}}=\sqrt[3]{\frac{E_0}{2B_\pi}}. \qquad (11)$$

The linear rigidity of the slab B_π equals:

$$B_\pi=\frac{B}{b}. \qquad (12)$$

where B is the rigidity of the entire cross section determined according to formula (54), kg/cm^2; b is the width of the cross section, cm.

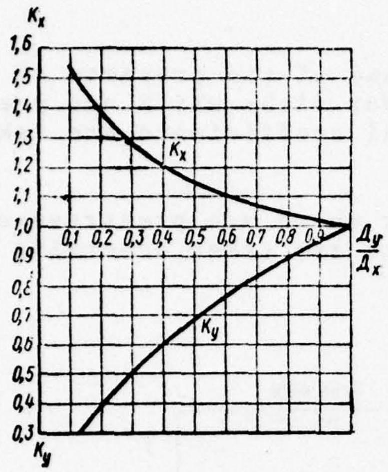

Fig. 58.--Values of the coefficients K_α and K_y as a function of the rigidity ratios.

The slab is considered infinite (in a mathematical sense) with a load in the center if the dimensions satisfy the condition

$$b > \frac{4}{a}, \qquad (13)$$

where b is the minimum dimension of the slab in thepplane (width) cm; a- is the parameter of slab rigidity, cm^{-1}.

In this case, if condition (13) is not observed, the slab cannot be considered infinite. However, in the limits up to b = 1/a (2-3), the determination of the calculated forces is possible with some approximation and can be carried out according to the formula for infinite slabs. If the dimension of the slab is b<2/a, the determination of the calculated forces can be carried out according to the formulas for calculation of the strips (see formulas 27-32).

In the case of orthotropic slabs, i.e. having dissimilar rigidity D_x and D_y in mutually perpendicular directions, calculation of the orthotropic nature can be carried out using values of the coefficients of K_x and K_y proposed by doctor of technical science B.S. Raieim-Boroslovskim [28,36] (Fig. 57).

The coefficients K_x and K_y are multiplied by the value of the bending moment in the center of the infinite isotropic slab, obtained by calculation, with rigidity D, equal to the larger of the values D_x and D_y. The calculated values of the moments in this case are determined according to the formulas:

$$M_x = K_x M, \qquad (14)$$

$$M_y = K_y M, \qquad (15)$$

where M is the bending moment in the center of a similar infinite isotropic slab with rigidity D.

For example, for a continuous slab, prestressed in one direction, with the calculated value of its rigidity D, with the determination of the bending moment, the rigidity will be the prestressed transverse cross section of the slab.

The calculated values of the positive and negative bending moments for other zones of the slab (other conditions of the effect of automobile load) are calculated by multiplying the bending moment obtained with the position of the load in the center, by the transitional coefficients (Figs. 58,59). These coefficients are changed as a function of the type of joining of the edges of contiguous slabs (edge

with joint connection or with free edge) and of the presence of pre-stressing in one or two directions. For slabs which are pre-stressed in one direction, the transitional coefficients are taken according to Fig. 58 [35].

For slabs not having pre-stressing or which are prestressed in two directions, the transition coefficients are taken according to Fig. 59 [35].

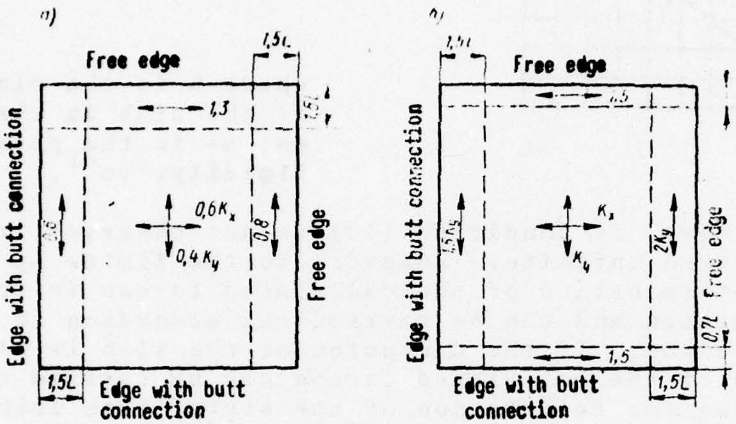

Fig. 58.--Values of transitional coefficients for single-base compressed, prestressed slabs of prefabricated pavements: a-for negative moments; b-for positive moments.

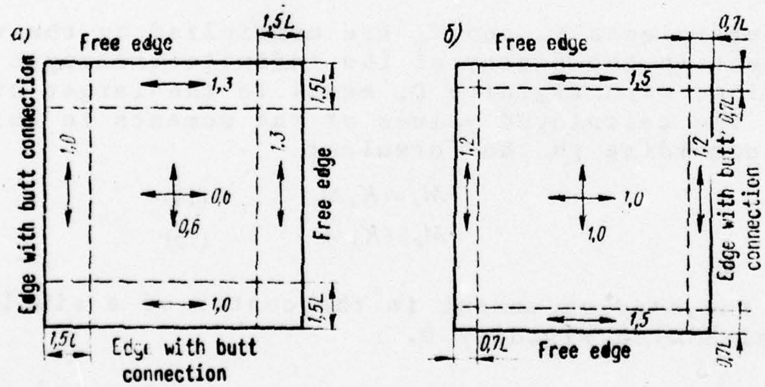

Fig. 59.--Values of transitional coefficients for reinforced concrete and double-base compressed, prestressed slabs of prefabricated pavements: a-for negative moments; b-for positive moments.

For calculations according to the hypothesis of an elastic semi-space, it is possible to assume the values of the dynamic elasticity moduli of grounds, obtained with calculation of the short-term effect of load, according to the data of doctoral science candidate Yu. M. Yakovleva (MADI), shown in Table 1, appendix I.

The dynamic elasticity moduli of groun are determined by means of tests with the installation of a dynamic stress (UDN) which, according to the value of the created forae and the time of its effect, simulatetthe effect of a wheel of a calculated truck, moving at a speed of 40-50 km/h. With the determination of the mathematical values of the dynamic moduli of grounds, we studied the vast, investigative material in the study and exploitation of road pavements.

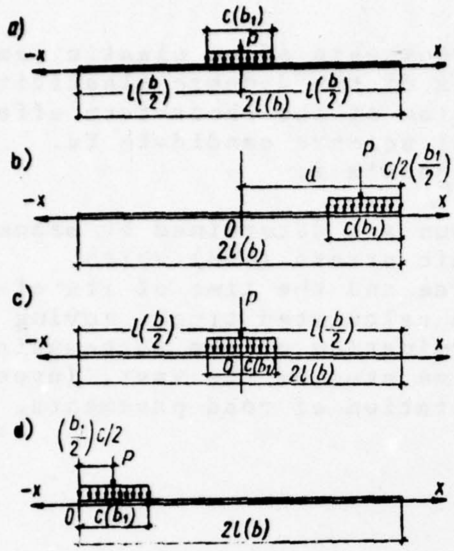

Fig. 60.--System of coordinates with calculation of the strips (in conditions of plane deformation): a-for inflexible strips with the position of the wheel in the center of the trip; b-for inflexible strips with position of the wheel near the edge of the strip; c-for flexible strips with position of the wheel in the center of the strip; d-for flexible strips with the position of the wheel near the edge of the strip.

The values of the Poisson coefficients of various grounds of listed in Table 2, Appendix I. The dynamic elasticity moduli of road-construction materials, according to the data of MADI, are listed in Table 3, Appendix I.

The possibility of carrying out a calculation of inflexible pavements of temporary roads, such as strips, worked out in conditions of plane deformation, was based on the study of candidate for technical science S.V. Konovalova, who established the values of the necessary coefficients close to the results of the theoretical solution, proposed by M.I. Gorbunovim-Posadovim, with actual work of slabs in pavements. Moreover, the calculated forces were determined separately for longitudinal and transverse direction as a function of the characteristics of the flexibility of the strip t. In the case of $t>10$, the slab belongs to the category of flexible (dimensionless) lanes, and in the case of $1\leq t\leq 10$, it belongs to the calculated category of inflexible road lanes. The characteristic of flexibility t (value of the dimensionless one) is also determined separately for the longitudinal and transverse directions.

With the calculation in longitudinal direction, the length of the slab is designated as 2l (where l is the half-length of the slab), and with the calculation in transverse direction, for the length of the slab, we take its width b, i.e. in formulas (16,17,18), instead of l it is necessary to substitute b/2, and instead of b it is necessary to substitute 2l.

If the slab operates without cracks (concrete, stressed), t (in longitudinal direction) is determined according to the formulas:

for the rectangular cross section

$$t=\frac{(1-\mu^2)\,\pi K_{E_0} E_0' b l^3}{(1-\mu_0^2)\,4E'I}\approx 10K_{E_0}\frac{E_0}{E}\cdot\frac{l^3}{h^3}; \qquad (16)$$

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for the cross section of the arbitrary form

$$t=\frac{(1-\mu^2)\pi K_{E_0}E'_0bl^3}{(1-\mu_0^2)4E'I}. \qquad (17)$$

In reinforced concrete slabs

$$t=\frac{(1-\mu^2)\pi K_{E_0}E'_0bl^3}{(1-\mu_0^2)4B}. \qquad (18)$$

The following designations are made in formulas (16-18): h,b,21 is the thickness, width and length of the slab; E' is the modulus of elasticity of the concrete, kg/cm^2; E'_0 is the modulus of deformation of the ground, kg/cm^2, taken according to the operating instructions for calculating flexible road covers (VSN-46-60); μ and μ_0 are the Poisson coefficients respectively for the material of the slab and of the ground; K_{E0} is the coefficient for the transition from the deformation modulus of the ground, recommended by the instructions VSN-46-60, to the modulus of ground deformation under the slab (taken according to the data given earlier); I is the moment of inertia of the weakest transverse cross section of the clab, cm^4; B-is the rigidity of the weakest cross section of the slab determined with calculation of the beginning of cracks $kgcm^2$ (see formula 54).

Corrected coefficients K_{E0} for the slabs of prefabricated pavements of temporary roads of the type of construction K_{E0}

Continuous	4
Cellular	3
Grate-like*	1.5

*The presented data refer to the grate-like designs, laid on draining ground, without which the exploitation of these slabs is not permitted.

Values of the calculated forces: the positive one and the negative one of the bending moments ~nd the maximum transverse forces are determined with the aid of the table dimensionless values $\bar{M}$ and $\bar{Q}$, for the determination of which it was necessary first to calculate the relative coordinates α and ξ of the load P and of the calculated cross section (Fig. 60).

For the inflexible lands, the relative coordinates are determined by the ratios:

$$\alpha=\frac{d}{l};\ \xi=\frac{x}{l},$$

where d is the absolute coordinate of the load P, cm; x is the absolute coordinate of the calculated cross section, cm; l is the half-length of the slab, cm.

For flexible lands, the relative coordinates are determined according to the expressions:

$$\alpha=\frac{d}{L};\ \xi=\frac{x}{L},$$

where L is the flexibility characteristic of the lane, cm.

With the calculation in longitudinal direction

$$L = l\sqrt[3]{\frac{\pi}{2t}}\,. \tag{19}$$

with the calculation in transverse direction

$$L = \frac{b}{2}\sqrt[3]{\frac{\pi}{2t}}\,. \tag{20}$$

For inflexible lands, with any position of the load, the beginning of the coordinate coincides with the middle of the land (Fig. 60, a,b).

To obtain the maximum positive bending moment M_{max}, the wheel is placed (Fig. 60,a) in the middle of the calculated land ($\alpha = 0$); according to Table 9, as a function of the value of t, we determine the dimensioness value of the maximum positive bending moment $\bar{M}_{max}$ for $\alpha=\xi=0$.

To obtain the maximum negative bending moment M_{min} it is necessary to place the wheel on the short edge of the slab at a distance of half the length of the area of its support from the butt end (Fig. 60,b); according to the value α = d/l (or α = d/b/2) in the same table we find the dimensionless value of the maximum negative bending moment $\bar{M}_{min}$.

Moreover, the values of α are determined as well as the dimensionless value $\bar{Q}_{max}$ with the aid of which we calculate the mathematical transverse force.

For slabs belonging to the calculated category of inflexible strips, the values of the calculated forces are determined according to the following formulas:

$$M_{макс} = \bar{M}_{макс}Pl, \tag{21}$$

$$M_{мин} = \bar{M}_{мин}Pl, \tag{22}$$

$$Q_{макс} = |\bar{Q}|_{макс}P. \tag{23}$$

In the case of the calculation in transverse direction in formulas (21-23) instead of the value of l, we substutite the value b/x.

Table 9

Flexibility coefficient	$\bar{M}_{max}$ at $\alpha=\xi=0$	$\bar{M}_{min}$ at α					$\lvert\bar{Q}\rvert_{max}$ at $\alpha=\xi$				
		0,6	0,7	0,8	0,9	1,0	0,6	0.7	0,8	0,9	1,0
0	0,32	−0,01	−0,04	−0,08	−0,14	−0,20	0,60	0,57	0,51	0,61	1
1	0,29	−0,01	−0,04	−0,09	−0,15	−0,21	0,59	0,55	0,53	0,69	1
2	0,28	−0,01	−0,04	−0,08	−0,14	−0,20	0,58	0,55	0,52	0,68	1
3	0,27	−0,01	−0,04	−0,08	−0,13	−0,19	0,58	0,55	0,52	0,67	1
5	0,25	−0,02	−0,04	−0,07	−0,12	−0,18	0,57	0,55	0,51	0,66	1
7	0,23	−0,02	−0,04	−0,07	−0,11	−0,17	0,57	0,55	0,50	0,65	1
10	0,22	−0,02	−0,03	−0,06	−0,10	−0,15	0,56	0,55	0,51	0,63	1

For the slabs belonging to the calculated category of flexible lands, the value of the calculated positive bending moment is determined as for the infinite length of the strip. The dimensionless value $\overline{M}_{max}$ in this case does not depend on α and is equal to 0.38 (see Table 10).

Table 10

$M_{макс}$ (1) при $\alpha=0$ (2)	$\overline{M}_{мин}$ (3) при α (4)			$\lvert\overline{Q}\rvert_{макс}$ (1) при α (2)		
	0	0,2	0,4	0	0,2	0,4
0,38	−0,32	−0,21	−0,13	1	0,66	0,51

(1) max
(2) at
(3) min
(4) at

With the calculation for the positive bending moment, the beginning of the coordinates coincides with the middle of the slab (Fig. 60,c), then $d = \alpha = 0$; $x = \xi = 0$. With the determination of the dimensionless value M_{min}, the wheel is placed near the edge of the slab (Fig. 60,d); moreover, the beginning of the coordinates coincides with the edge cross section of the slab. In the latter case $\alpha = C/2L$; in conformity with the latter value α according to Table 10, we determine the dimensionless value $\overline{M}_{min}$. Moreover, the positions of the load are determined as well as the dimensionless value $|\overline{Q}|_{max}$ according to Table 10.

The calculated forces for the slabs belonging to the calculated categpru pf flexible lands, are determined according to the formulas

$$M_{макс} = 0{,}38PL, \tag{24}$$

$$M_{мин} = \overline{M}_{мин}PL, \tag{25}$$

$$Q_{макс} = |\overline{Q}|_{макс}P. \tag{26}$$

Since the calculation is carried out according to the maximum values of the forces, it is necessary to determine the values of the maximum positive and negative bending moments and the maximum transverse force. In connection with this, in the tables $\overline{M}_{max}$, $\overline{M}_{min}$ and $\overline{Q}_{max}$ are placed with their maximum values according to absolute value, necessary for the calculation.

The listed formulas may be used for the calculation with regard to some coefficients, taking into account the special features of the operation of the slabs of temporary road pavements:

1) coefficient $K_{\Phi} = 0.9$, taking into account the divergence between the values of the theoretical and actually emerging forces;
2) coefficient K_D, taking into account the dynamic effect of load (Table 11);
3) coefficient of overloading n, equal to 1.3, taking into account the possible deviations of the value of actually effective load from the calculated one (introduced with the calculation for strength).

The enumerated coefficients belong equally to the calculation in longitudinal direction as well as in transverse direction.

Table 11

Calculated position of the wheel	Coefficient of dynamic K_D	
	in the case of a continuously driven over surface	in the case of a grid-like driven over surface
Wheel in the middle part of the slab	1.1	1.25
Wheel on the butt end of the slab	1.5	1.5

The values of the forces calculated in longitudinal direction, are perceived by the entire width of the slab, and the ones calculated in transverse direction only by a part of the slab length, being in the given case the transverse cross section for the calculated direction. Thus, with the calculation in transverse direction it is necessary to determine the value of the forces imposed on 1 m of the middle part of the slab by means of dividing up the value of the obtained forces over the length of the distribution of forces l_p (Table 12). In the calculation, the pressure of the wheel P is assumed to be concentrated in the center of the support area. With calculation in the longitudinal direction, such an assumption distorts the actual value of the force little; with the calculation in transverse direction, the distortion due to the substitution of the actual uniformly distributed load of the concentrated force gives a significant divergence. This divergence between the actual forces and the calculated ones for concentrated forces is asslowed for by the coefficients of the reduction of K_{pr} (Table 13), which are introduced, such as $1/l_p$, only with the calculation in transverse direction.

Table 12

Type of construction	With calculation for:	l_p, m
Stressed-reinforces	M_{max}	2.2
	M_{min}	1.6
	Q_{max}	1.3
Reinforced concrete	M_{max}	1.7
	M_{min}	1.2
	Q_{max}	1.0

With consideration of the formula stated above for determination pf tje calculated forces in prefabricated slabs of temporary automobile pavements, calculated as a lane, the following form was used:

with the calculation for stability in longitudinal direction

$$M_{\text{макс}} = 0{,}9 K_{\text{д}} n \overline{M}_{\text{макс}} P l(L), \quad (27)$$

$$M_{\text{мин}} = 0{,}9 K_{\text{д}} n \overline{M}_{\text{мин}} P l(L), \quad (28)$$

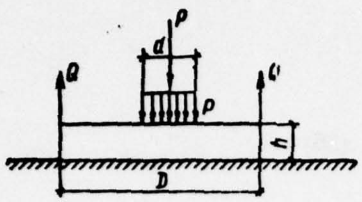


Fig. 61.--Calculated scheme of a round slab on an elastic base.

$$Q_{max} = 0{,}9 K_{д} n |\bar{Q}|_{max} P. \quad (29$$

When calculating for stability in transverse direction (per 1 m)

$$M_{max} = \frac{0{,}9}{l_p} K_{np} K_{д} n \bar{M}_{max} P \frac{b}{2} (L), \quad (30$$

$$M_{min} = \frac{0{,}9}{l_p} K_{np} K_{д} n \bar{M}_{min} P \frac{b}{2} (L), \quad (31$$

$$Q_{max} = \frac{0{,}9}{l_p} K_{np} K_{д} n |\bar{Q}|_{max} P. \quad (32$$

Table 13.

Width of the calculated wheel b_1, cm	Values of K_{stab} with a calculation for:			
	M_{max} on continuous and irreg.-shaped slabs	M_{min}		Q_{max}
		t <10	t>10	
60	0.5	0.85	0.7	0.5
40	0.65	0.95	0.85	0.6

With the calculation for hardness in formulas (27)-(32), the coefficient of overloading n is assumed to be equal to 1.

The calculation of the prefabricated slabs of solid road slabs, having a round, hexagonal, square or other similarly enumerated contour in the plane, usually is carried out according to the method of doctoral science candidate Prof. I.A. Mednikov for calculating *round slabs* on a ground base, assumed to be on a linear-deformed half space [1,50,51].

The expressions for the internal forces in the different cross sections of the slab (Fig. 61) according to I.A. Mednikov, have the following form:
for a loaded area of a slab ($r \leq b$)

$$M_r = \frac{P}{16\pi} \left\{(1-\beta^2)\left[(1-\mu)-(3+\mu)\left(\frac{r}{b}\right)^2\right] - 4(1+\mu)\ln\beta\right\}, \quad (33$$

$$M_t = \frac{P}{16\pi} \left\{(1-\beta^2)\left[(1-\mu)-(1+3\mu)\left(\frac{r}{b}\right)^2\right] - 4(1+\mu)\ln\beta\right\}, \quad (34$$

$$Q_r = \frac{-P_r}{2\pi b^2}(1-\beta^2); \quad (35)$$

for the unloaded zone (r>b)

$$M_r = -\frac{P}{16\pi}\left\{(1-\mu)\left[\beta^2-\left(\frac{b}{r}\right)^2\right]+(3+\mu)\left[1-\left(\frac{r}{b}\right)^2\beta^2\right]+\right.$$
$$\left.+4(1+\mu)\left(\ln\frac{r}{b}+\ln\beta\right)\right\}, \qquad (36)$$

$$M_t = \frac{P}{16\pi}\left\{(1-5\mu)+(1+3\mu)\left(\frac{r}{b}\right)^2\beta^2-(1-\mu)\left[\beta^2+\left(\frac{b}{r}\right)^2\right]-\right.$$
$$\left.-4(1+\mu)\left(\ln\frac{r}{b}+\ln\beta\right)\right\}, \qquad (37)$$

$$Q_r = -\frac{P_r}{2\pi b^2}\left[\left(\frac{b}{r}\right)^2-\beta^2\right]. \qquad (38)$$

The maximum bending moment in the center of the slab

$$M_{\text{макс}} = \frac{P}{16\pi}\left[(1-\beta^2)(1-\mu)-4(1+\mu)\ln\beta\right]. \qquad (39)$$

In formulas (37)-(43) $\beta = 1{,}1b/a$ is the coefficient characterizing the dimensions of the loaded part of the slab. Here, a is the length of one side of a hexagonal slab. The solution of I.A. Mednikova is applicable to the condition, if

$$a \leqslant 1{,}92h\sqrt[3]{\frac{1-\mu_0^2}{1-\mu^2}\cdot\frac{E'}{E_0'}}. \qquad (40)$$

In a series of cases, especially in the case of intense and heavy traffic, prefabricated road pavements are constructed on an artificial, more stable base.

The calculation of the base in such cases is expeditiously carried out starting from the value of the critical compressive stresses emerging in the base of a solid road pavement. The critical stress for the case of a round, flexible stamp, in the case of which the zones of destruction are still absent (zones of shift), is determined according to the formula of N.P. Puzirevsk [53,55]:

$$p_{\text{кр}} = \frac{\pi\left(\gamma h+\frac{c}{\operatorname{tg}\varphi}\right)}{\operatorname{ctg}\varphi+\varphi-\frac{\pi}{2}}+\gamma h_{\text{ш}}, \qquad (41)$$

where γ is the volumetric weight of the ground; h_{sh} is the value of stamp immersion (γh_{sh} is overload); c is coupling; ϕ is the angle of internal friction.

It is possible to determine the compressive stresses permissible for the given material or ground according to formula (41). Moreover, it must be taken into account that with repeated effect of the load, the value p_{kp} is reduced with the introduction of a coefficient equal to 0.6. Moreover, Moreover, it is necessary to take into account the inhomogeneity of the stable characteristics of the ground with the aid of the coefficient of inhomogeneity, equal to 0.5. The calculated critical stress equals

$$p_{\text{кр}\cdot\text{р}} = p_{\text{кр}}K_{\text{п}}K_{\text{н}}, \qquad (42)$$

where p_{kp} is the critical stress determined according to formula (41) kg/cm^2, K_π is the coefficient taking into account the repeated nature of the effect of load equal to 0.6; K_H is the coefficient taking into account the inhomogeneity of the stable properties of the ground equal to 0.5.

The values of the critical stresses, calculated according to formula (42) for different grounds in the case of their change with relative humidity according to the original data of Ref. [52] are listed in Table 14.

In conditions of a flat problem for the absolute ly flexible land, Prof. N.N. Maslovim proposed [55] the following relationship for determining the critical stress:

$$p_{\kappa p}=\frac{\pi\gamma\left(2b\operatorname{tg}\varphi+h_{\text{загл}}+\dfrac{c}{\gamma+\operatorname{ctg}\varphi}\right)}{\operatorname{ctg}\varphi+\varphi-\dfrac{\pi}{2}}+\gamma h_{\text{imm}},$$

where 2b is the width of the land; h_{imm} is the depth of its immersion.

Same designations as before.

Table 14

Name of ground	Relative moisture W/W_T	Stat.modul. of elasticity	Angle of intern. friction φ	Coupling	$p_{\kappa p.p}$*, kg/cm^2
Large-grained sand	0,70—0,75	1300	43	0	1,49
Medium grained sand	0,70—0,75	1200	40	0	1,19
Fine-grained sand	0,70—0,75	1000	38	0	0,827
Dusty sand	0,70—0,75	900	36	0	0,641
Sandy loam	0,60	530	30	0,30	2,51
	0,65	450	27	0,23	1,73
	0,70	400	25	0,18	1,28
	0,75	360	23	0,13	0,875
	0,80	320	22	0,09	0,605
Loam . . .	0,60	600	24	0,40	2,64
	0,65	420	21	0,30	2,00
	0,70	340	18	0,22	1,39
	0,75	280	15	0,15	0,771
	0,80	240	13	0,10	0,494
	0,85	210	11	0,07	0,335
	0,90	200	10	0,05	0,241

*$p_{kp.p}$ calculated with regard to load on a reinforced concrete slab of medium thickness 8 cm.

The formula of N.N. Maslova is used for sohesive grounds, with the condition that their angle of internal friction if ϕ>5-7°.

The calculated critical stress, obtained according to formula (42) must be compared with the value of reactive pressure on the surface of the ground. In this case, if

$$p_{\text{кр.р}} \geqslant p_{\text{react}} \qquad (43)$$

the calculation is concluded. If condition (43) is not fulfilled, then construction of a base layer above the ground of more stable materials is required. The thickness of this layer is determined on the basis of the known Bussinesk equation

$$h_{\text{axes}} = \frac{R}{\left[\left(\frac{1}{1-\frac{p_{\text{кр.р}}}{p_{\text{react.}}}}\right)^{2/3} - 1\right]^{1/2}}, \qquad (44)$$

where R is the radius of the circle equal in size to the track of the wheel imprint, cm.

The reactive pressures emerging under the slab may be calculated according to the solutions of O.Ya. Shexter and M.I. Gorbunov-Posadova. Under the center of the infinite slab, the reactive pressure equals

$$p = \bar{p}_{\text{н}} a^2 P, \qquad (45)$$

where $\bar{p}_{\text{н}}$ is the dimensionless value of reactive pressure taken according to table 15 as a function of the listed thickness of the elastic layer aH; a is the parameter of slab rigidity, cm^{-1}; P is the value of the load, kg.

Table 15

aH	0	0,05	0,10	0,20	0,30	0,40	0,60	0,80	1,00	1,50	2,00	3,00	∞
$\bar{p}_{\text{н}}$	∞	0,791	0,563	0,405	0,338	0,299	0,257	0,235	0,221	0,205	0,198	0,194	0,192

Under the edge of the slab, the reactive pressure equals

$$p_{\text{reac}} = \bar{p}_{\text{к}} \frac{\bar{p}_{\text{н}}}{\bar{p}_{\infty}} a^2 P, \qquad (46)$$

where $\bar{p}_{\text{К}}$ is the dimensionless value of reactive pressure, taken according to Table 16 as a function of the given distance δ (from the center of load application up to the edge of the slab). The given distance δ is determined according to formula

$$\delta = ad,$$

where d is the actual distance from the center of load application to the edge of the slab, cm; a is the parameter of slab rigidity, cm^{-1}.

In formula (46), the values $\bar{p}_H$ are taken according to table 15 as a function of the given thickness of the compressed layer aH, but $p_\infty = 0.192$ according to the data of the same table.

Table 16

λ	0	0,1	0,2	0,4	0,6	0,8	1,2	1,6	[illegible]
$\bar{p}_K$ at $\xi=\eta=0$	1,06	0,98	0,91	0,76	0,62	0,48	0,24	0,10	0,07

The calculated rigidity of the slab cross section may be assumed to be equal to its cylindrical rigidity for non-reinforced reinforced concrete and prestressed prefabricated road slabs, operating in the stage of exploitation without the emergence and discovery of cracks.

When calculating the reinforced concrete road slabs (without prestressing of the reinforcement) for stability and durability, it is necessary to take into account the emergence and discovery of cracks in them in the elongated zone of the concrete cross section. The rigidity of the calculated cross section at bend with consideration of the presence of cracks in the case of one-time or extended (constant) effect of load is calculated according to the formula of prof. V.I. Murashev:

$$B=\frac{E_a}{\psi}W_a(h_0-x_c), \tag{48}$$

where E_a is the elasticity modulus of the reinforcement, kg/cm^2; ψ is the coefficient taken according to table 4 of application I; W_a is the conditional, elastic-plastic moment of resistance, cm^3, calculated according to the formula:

$$W_a=F_a(h_0-0{,}5x_c). \tag{49}$$

Here H_0 is the useful height of the cross section, cm; F_a is the area of the elongated reinforcement, cm^2, x_c is the height of the compressed zone of concrete, cm, calculated according to the formula:

$$x_c=h_0\xi. \tag{50}$$

$$\xi=-\frac{\alpha}{2}+\sqrt{\left(\frac{\alpha}{2}\right)^2+\alpha}, \tag{51}$$

Here $$\alpha=\frac{3F_aE_a}{100h_0E_б}, \tag{52}$$

where E_b is the elasticity modulus of the concrete of a given brand, kg/cm^2.

With the multiple effect of repeated load, the deformations of the compressed zone of the concrete become elastic, and the concrete of the elongated zone disconnected from the work. In this case, the coefficient α is calculated according to the formula

$$\alpha=\frac{F_aE_a}{bh_0E_б}, \tag{53}$$

and the rigidity of the cross section is determined with $\psi = 1$

$$B = E_a W_a (h_0 - x_c) = F_a E_a (h_0 - 0{,}5x_c)(h_0 - x_c). \quad (54)$$

Stresses may arive in road slabs of large dimensions in the plane and with a considerable thickness in the presence of a temperature drop along the thickness of the slab, because of the impossibility of a temperature warping. These stresses may be determined according to the formulas of Timoshenko-Westergard and Bredbruki [52].

The slabs of prefabricated road pavements usually have comparatively small dimensions (especially thickness), and moreover, the frequent ribbed designs f the slabs having still less gravity compared with continuous slabs, are widely used. These circumstances make it possible to carry out a calculation of the prefabricated road slabs only with the effect of multiple, repeated automobile load.

The change of the water-heat regime must be considered not only with the calculation of the pavement, but with the calculation of the entire road cover, including the upper layer of the earth road bed. Depending on the road-climate zone, the conditions for freezing and the types of grounds, the conditions for leading off water with the planning of the road topping, its necessary frost resistance must be guaranteed.

The thickness of the road cover necessary for the condition of frost resistance is determined according to the method of Prof. N.A. Puzakov [27].

If conducting off water from the ground road bed is difficult or cannot be guaranteed, then the determination is made according to the conditions necessary for drying the thickness of the drainage layer in accordance with the method worked out by Prof. A.Y. Tulaevim [16].

The calculation of the slabs of prefabricated road pavements is carried out according to the method of calculated limit conditions. Moreover, the calculation can be carried out according to the following limiting conditions:

first--from exhaustion of the carrying capacity according to durability and stability;
second--from the excessive deformations;
third--from the emergence and inadmissible finding of cracks.

The first limit condition is checked for all the slabs of the road cover, independent of the material of which it is made. The second limiting condition in the practice of calculating solid road pavements, with the exception of temporary ones, has not yet found its concrete expression. The third limit condition is characteristic only for reinforced constructions of road slabs.

The equation of the following general form is used to calculate for stability:

$$nN^{\text{н}} \leqslant f(m, K, R^{\text{н}}, S), \quad (55)$$

where n is the coefficient of possible overload; N^H is the force from the standard automobile load; f is the function in conformity with the character of the emerging force; m is the coefficient of working conditions, taking into account the possible deviations of the actual conditions of design exploitation from the planned ones; K is the coefficient of homogeneity of the construction material taking into account the possible reduction in the stability of the design due to the inhomogeneity of the properties of the raw material and the incompleteness of the manufacturing technology; R^H is the standard limit of material stability

of the construction; S is the geometric characteristics of the cross section of the calculated element.

Condition (55) consists in the fact that the maximum possible force in the element was not larger than its minimum stability. If this condition is fulfilled, then the required stability of the design is considered guaranteed. The calculation for stability is carried out for the effect of the calculated load, equal to the normal one, multipled by the coefficient of overload and by the coefficient taking into account the dynamic character of its effect.

The calculation for durability is carried out in two stages:

a) calculation for the stability of normal cross sections of the slab (cross section, perpendicular to its longitudinal and transverse axes);
b) calculation for durability of inclined cross sections of the slab (or the calculation for the main elongation stresses with consideration of the influence of the repetition of the effect of load).

In the calsulation for durability, we determine the characteristics of the stress cycle emerging at the more loaded points of the construction under the effect of multiple repetition of the load. The emerging stresses must not exceed the permissible ones taken with consideration of the repeated effect of load. The calculation is carried out for the effect of the multiple, repeated load, determined without calculating the overload coefficient, but with calculation of the coefficient of dynamism. Such an approach to determining the values of load is explained by the fact that the character of the effect of wheels of moving automobiles on a pavement is dynamic, in connection with which it is always impossible to introduce the coefficient of dynamic effect.As far as the overload is concerned, the majority of automobiles do not have it and even follow with underloading. Consequently, in the case under examination, the coefficient of overloading n cannot be introduced. In individual partial cases, the introduction of n into the calculation for stability may turn out to be justified (as for example in the calculation of slabs for gauge pavements, working under constant automobile overload), but it must be based on factual data about traffic.

For the calculation of the second and third limit condition, we can use equations similar to condition (55).

The calculation on the formation of cracks (for prestressed slab designs) and their disvoery (for slabs made of reinforced concrete) was also carried out with consideration of the influence of the repeated effect of load. Depending on the designation of the road: city or out-of-town, special designation (industrial plant, stone quarry, agricultural, forest), temporary, etc. Constructional standards and laws (SNand P) provide for different values of standard automobile loads.

For main city streets in conformity with CNandP II-K2-62 [32], the load must be taken according to the scheme of an arbitrary automobile H-30.

Weight of the loaded automobile	30 t
Pressure of the read axle	12 t
Number of rear axles	2
Distance between the rear axles	1.6 m
Width of gauge of the rear axles	1.9 m
Width of the rear incline	0.6 m
Length of contact of the rear incline with the pavement (according to the direction of movement)	0.2 m

The weight of the most loaded axle for out-of-town automobile roads of different technical categories must be taken according to Table 17 [32].

Table 17

Name of the weight parameters	Group A	Group B
Axle weight (load on the road, transmitted by the wheels of a single, more loaded axis), t:		
a) with a distance between adjacent axes of 3 m and more	10	6
b) with a distance between adjacent axes of 3 m	9	5

Automobiles and tracktor and trailer rigs of group A are intended to be used on automobile roads of the Ist and IInd *category of the general network* of the Soviet Union, having improved capital pavements, and also on automobile roads of other categories and city roads, the travelled part of which is calculated on the passage of automobiles of this group. The automobiles and track and trailer rigs of group B are intended for exploitation on all automobile roads of the general network of the Soviet Union. Automobiles and truck and trailer rigs with a full weight of more than 1.5 t must have wheels with pneumatic tires, providing a transmission of the axial weight onto the surface of the road with medium calculated specific pressure not more than 6.5 kg/cm^2 for group A and not more than 5.5 kg/cm^2 for group B.

The standard automobile load with calculation of prefabricated pavements of highways of special designation (industrial plants, stone quarries, agricultural, etc) and of temporary highways are taken in accordance with the standard documents on planning these constructions.

The coefficient of overload n with the calculation of prefabricated pavements of city and out-of-town automobile, and also temporary roads, usually is assumed to be equal to 1. For temporary highways, intended to permit specific automobile loads, the values of the coefficient of overload is assumed to be much greater than 1 (up to 1.4 inclusive). So, for example, when calculating prefabricated pavements of forest automobile roads, the coefficient of overload is assumed to be equal to 1.3.

Different values are assumed for the coefficient of the dynamic effect of load as a function of the designation of the road, the type of slab connection and the place of application ot automobile load to the slab. For prefabricated pavements of main roads, having as a rule reliable joint connections, the coefficient of the dynamic nature of the effect of load with calculation for stability is assumed to be the same for the center and for the edge of the slab--1.2.

When calculating the prefabricated pavements of these roads for durability, the considered evenness and, consequently, the sufficiently high (compared with temporary roads) moving speed of automobile traffic, the coefficient of the dynamic feature of the effect of load are assumed to be equal to 0.7; this coefficient was obtained by us and by a series of other investigators experimentally and characterizes the influence of the elastic-viscous nature of the ground base, and also of the interia properties of the base in their stressed-deformed state in the case of a short-term dynamic load. For prefabricated pavements of temporary roads, not having a reliable transmission of load to the contiguous slabs, the coefficient of the dynamic nature of the effect of load with a calculation for stability and sturdiness is taken differently for the center and for the edge of the slabs: for the center of the slabs K_d = 1,1; for the edge (butt end) of the slabs K_d = 1.5.

The reduction of the value of K_d for the center of the slabs on temporary roads (with their calculation for stability) compared with the value K_d = 1.2 for permanent roads is connected with the fact that on temporary roads, the pavement is constructed continuously from slabs of small widths or of the gauge type. This excludes an increase of the calculated load due to the influence of the adjacent wheel.

With a calculation of the prefabricated road slabs for stability under the effect of forces emerging with their transportation and installation, the gravity of the slab is introduced into the calculation with the coefficient of dynamism, equal to 1.5; moreover, the coefficient of overloading for the gravity of the slab is not introduced.

The coefficient of the working conditions m in calculating the construction for stability may be greater or less than 1 depending on the deviation of the real working conditions from the calculated ones and how they influence the stability of the construction. In this case, when these deviations are not known with the planning, the coefficient of working conditions m is assumed to be equal to 1 in first approximation. The coefficients of working conditions of the construction as a whole m, of the concrete m_b and of the reinforcement m_a are established on the basis of statistically working out experimental data. The homogeneity coefficients of the materials were established in a similar manner. By statistically working out the results of experiments for the stability of concrete specimens in laboratory constructed objects, G.G. Mudrovim and B.P. Antonov obtained the mean value for the coefficient of homogeneity K_b of road (and airport) concrete according to elongation at bend, equal to 0.7. The coefficient of homogeneity of reinforced steel K_a is recommended by SNiP II-B.1-62 as follows: reinforced steel of class A-I and A-II-0.9; the reinforced steel of class A-III and A-IV is 0.85; ordinary and high strength wire is 0.80.

The standard resistances of road concrete and the initial elasticity moduli of concrete are taken according to GOST 8424-63 "road concrete" and CNiP II-V.1-62 as a function of its planned brand in accordance with the data of table 5, appendix I.

The calculated resistances of the concrete when calculating the slabs made of prestressed or ordinary reinforced concrete for stability and for the formation and discovery of cracks are taken in accordance with the recommendations of SNiP II-B.1-62 "Concrete and reinforced concrete constructions. Planning standards" and GOST 8424-63 "Road Concrete" according to the data of Table 6, appendix I.

The Poisson coefficient μ for road concrete is assumed equal to 0.15.

The calculated resistances of the different types of reinforcements, assumed with the calculation of reinforced road slabs for stability, are listed in Tables 7 and 8, appendix I.

A method for calculating concrete and reinforced concrete slabs of prefabricated pavements on an elastic base will be explained below.

The indicated method has the following special features:

1. The basic limit condition of a reinforced rigid pavement is the exhaustion of its bearing capacity according to the endurance of normal or inclined cross sections.

2. In addition to a calculation for endurance, a calculation is carried out for stability and crack resistance.

As far as the calculation for the influence of the repeated effect of load on the calculation of the base, this problem is still being worked out.

10. Method for Calculating Reinforced Concrete Slabs

Both the method for calculating reinforced concrete slabs as well as the method explained in 11 for calculating slabs from prestressed reinforced concrete, as the basic, determining calculation of the limit condition, include the exhaustion of the bearing capacity according to the durability of the normal or inclined cross sections. The fact is that the pavements of highways, among them rigid, i.e. concrete and reinforced concrete ones, operate under the effect of multiple dynamic loads from the wheels of automobile transport.

Many studies of domestic /10,15,16,21,28,39/ and foreign /52/ scholars give evidence of the fact that working capacity of road pavements is a function of the amount and the composition of the traffic.

The calculation of non-rigid road pavements is completely based on the calculation of the multiple, repeated effect of automobile transport /21,54/. The calculation of rigid pavements has also been worked over in the direction of a more complete calculation of the quantity and composition of traffic.

The calculation included first in the method for calculating rigid road pavements for durability of normal and inclined cross sections substantially improves the calculation of the repetition of the effect of load.

In addition to the calculation for durability, a calculation is also carried out for stability, which is necessary by dint of the static effect of the automobiles taking place when they stop on the pavement. In addition, this calculation is necessary for a comparison with the calculation for durability for the maximum effect on the pavement. The method presented below for calculating reinforced concrete and prestressed pavements is also applicable to concrete, sand-concrete, and claydite (clay filler) prefabricated and monolithic pavements, to pavements made of silicate concrete, lithium slags and other similar materials. As is seen from the material of Chapter 1, by dint of the design and technological special features of the construction of rigid pavements, they are classified into slabs of different dimensions. The separation of a rigid pavement into slabs substantially changes the effect of load on them depending on where the wheel of the calculated automobile is located on the slab.

Fig. 62 shows diagrams of moments obtained by S.V. Konovalov. From the drawing it is clear that not only the size, but the sign of the bending moment emerging in the slab changes as a function of the point of application of load on the slab. It is evident that the disposition of the automobile on the slab may be any, but with an appropriate increase in the dimensions, two or several wheels may be situated on the slab simultaneously.

In addition, as was obtained in our experiments and in the experiments of other investigators, the edge zones of the slab operate under conditions different from the central ones. The edge strips partially lost contact with the base, due to the warping of the slabs because of temperature deformations, and the effect of load on them is largely determined by the degree of implication of contiguous slabs in the work of the edge strip.

Since in the butt ends, along the long sides, in the middle part of the pavement the slabs are connected with different design mechanisms (see Chapter 1), and the long sides of the edge parts of the pavement may remain free, there is no doubt that the value of the emerging force and its sign depend not only on the place where the automobile tire is situated on the slab, but on the character of joining of the slabs with each other.

In order to decrease the volume of the calculated operations, without significant errors in the obtained values, the method provides for determining the calculated forces in the lower zone of the slab with a central disposition of the load. All the remaining forces are found, according to the tables or according to the graphs, depending on the type of slab joining, the character of their reinforcing, the zones of the slab and the place where the wheel of the calculated automobile is situated on it.

The explained method for calculating slabs of unstressed reinforced concrete may be used in calculating prefabricated pavements of permanent as well as temporary roads with consideration of the difference in the methods for determining the bending forces (see § 9).

In connection with this fact, in the majority of cases it is recommended that the calculation for durability, the calculation of the slabs of prefabricated pavements of highways made from unstressed reinforced concrete be carried out in the following sequence:

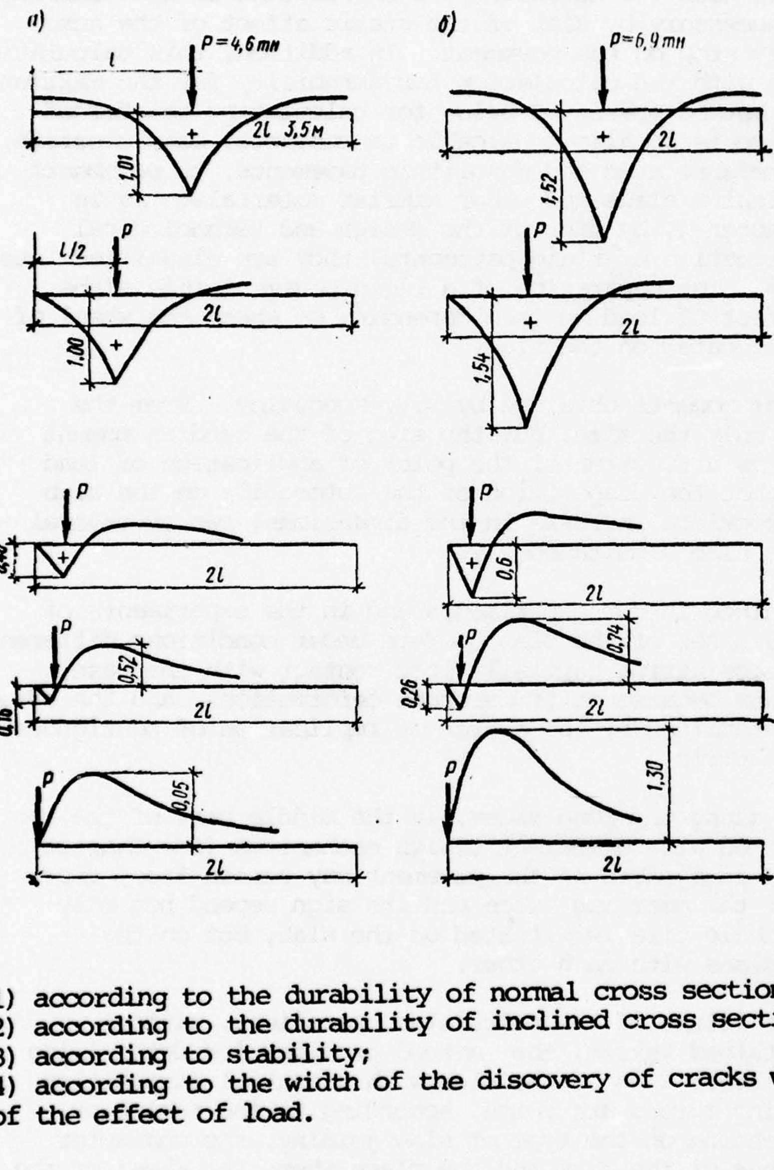


Fig. 62.--Drawings of the bending moments in a prefabricated road slab of the gauge type:

a--with load 4.6 t;
b--with load 6.9 t.

1) according to the durability of normal cross sections;
2) according to the durability of inclined cross sections;
3) according to stability;
4) according to the width of the discovery of cracks with regard to the repetition of the effect of load.

The calculation according to these indicators is carried out separately for the longitudinal and the transverse cross section of the slab in accordance with the recommendations of the head of CNiP II-V.1--62 "Concrete and Reinforced Concrete Constructions. Planning Standards".

When calculating for the durability of normal cross sections of a slab (i.e. cross sections normal to the longitudinal or transverse axes of the slab) made of ordinary reinforced concrete, the maximum edge compressive stress in the concrete σ_b must not exceed the calculated resistances of the concrete to compression at bend R_i' taken with consideration of the influence of the multiple effect of load, and the maximum stresses in the longituidnal extended reinforcement σ_a--the values of the calculated resistance of the reinforcement R_a', also taken with consideration of the multiple effect of load, i.e. the following conditions must be satisfied:

a) for compressed concrete:

$$\sigma_б \leqslant R'_и; \quad (56)$$

b) for an elongated reinforcement

$$\sigma_а \leqslant R'_а. \quad (57)$$

The normal stresses in the concrete and in the reinforcement with the calculation of the prefabricated reinforced concrete slab for durability are calculated according to the given characteristics of its cross section (with the assumption of elastic work).

The given characteristics of the slab cross section in this case are determined without calculating the area of the elongated concrete.

When calculating the reinforced concrete slabs made of heavy concrete for durability, to determine the stresses, the ratio of the elasticity modulus of the reinforcement E_a to the arbitrary modulus of elasticity of the concrete E_b' with multiple application of load (coefficient of reduction) n'=E_a/E_b' must be taken according to Table 18.

Table 18 Coefficients of the reduction of n' for calculation for durability of reinforced concrete designs made of heavy concrete.

Planned concrete brand	300	400	500 and higher
Values of the coefficient n'	20	15	10

Note: When calculating the reduced geometric characteristics of the cross section of the prestressed element, the coefficient of reduction is assumed to be equal to n' = E_a/E'b.

The moment of inertia of the rectangular cross section of the reinforced concrete slab without calculation of the elongated concrete, with the determination of stress from the effect of the positive bending moment is determined according to the formula

$$I_п = \frac{bx^3}{3} + n'F_а(h_0 - x)^2 + n'F'_а(x - a'_а),^2 \quad (58)$$

where b is the width of the concrete of the compressed zone of the cross section, cm; x is the height of the compressed zone of the cross section, cm; n' is the coefficient of reduction taken according to Table 18; F_a is the area of the lower reinforcement, cm^2; Fa' is the area of the upepr reinforcement, cm^2; a_a'- is the distance from the center of gravity of the upper reinforcement up to the upper grain of the cross section, cm; h_0 is the effective height of the cross section with the effect of the positive bending moment, cm, equal to $h_0 = h-a_a$; h is the thickness of the slab, cm; a_a is the distance from the center of gravity of the lower reinforcement to the lower grain of the cross section, cm.

Moreover, the height of the compressed zone of the rectangular cross section x is determined from the condition

$$0,5bx^2 = n'F_a(h - x - a_a) - n'F'_a(x - a'_a), \quad (59)$$

as the root of the quadratic equation.

Formulas (58) and (59) may be used for determining the moment of inertia and the height of the compressed zone of the T-cross section (with the flange of a beam in the compressed zone), if the neutral axis passes within the limits of the flange (with width b).

When determining the stresses from the effect of the negative bending moment, the moment of inertia of the reduced rectangular cross section is calculated according to eq. (58) substituting b for b', x for x' and h_0 for h_0', where b' is the width of the concrete of the compressed zone of the cross section with the effect of the negative bending moment, cm; x' is the height of the compressed zone of the cross section with the effect of the negative bending moment, cm; h_0' is the effective height of the cross section with the effect of the negative bending moment, cm, equal to $h_0' = h_0 - \alpha'_a$.

Moreover, the height of the compressed zone of the rectangular cross section x is determined from the condition (59) with substition of b for b/ and x for x', as the root of the quadratic equation.

The normal stresses of the cycle in the extreme lower grain of the concrete of the calculated cross section are determined according to the following formulas:

a) from the effect of the positive bending moment M_{max};

$$\sigma_{б.max} = \frac{M_{max}}{I_п} y_н, \quad (60)$$

where y_n is the distance from the neutral axis to the extreme lower grain of the cross section, cm; I_π is the moment of inertia of the cross section without calculating the elongated concrete with the effect of the positive bending moment, determined according to formula (58);

b) from the effect of the negative bending moment M_{min}.

$$\sigma_{б.min} = \frac{M_{min}}{I'_п} y_н, \quad (61)$$

where y_B is the distance from the neutral axis to the extreme upper grain of the cross section, cm.

The normal stresses of the cycle in the lower reinforcement are determined according to the formulas:

a) from the effect of the positive bending moment

$$\sigma_{a\,max} = n' \frac{M\,max}{I_{II}} y_a, \qquad (62)$$

where y_a is the distance from the neutral axis to the center of gravity of the lower reinforcement, cm; n' is the coefficient of reduction taken according to Table 18;

b) from the effect of the negative bending moment

$$\sigma_{a.\,min} = n' \frac{M\,min}{I_{II}} y_a. \qquad (63)$$

The normal stresses in the upper reinforcement are determined according to formulas (62) and (63) substituting y_a for y_a',
where y_a' is the distance from the neutral axis to the center of gravity of the upper reinforcement, cm.

According to the obtained values of normal stresses, we determine the characteristics of the cycle of stresses in the edge grains of the concrete and in the upper and lower reinforcement ρ_b and ρ_a, as a function of which we determine the methematical resistance of the concrete and of the reinforcement with the calculation for durability.

The calculated resistance of the heavy concrete to compression and elongation at bend in the calculation of reinforced concrete (and prestressed) slabs for durability, and also according to the formation of cracks with multiple, repeated load R_i' and R_T are calculated by multiplying the corresponding mathematical resistances of the concrete R_i and R_T, determined according to Table 6, appendix I, by the coefficient K_{ρ_b} taken according to Table 19 as a function of the characteristic stress cycle in the concrete:

$$\rho_б = \frac{\sigma_{б.мин}\,min}{\sigma_{б.макс}\,max} \qquad (64)$$

where $\sigma_{b.min}$, $\sigma_{b.max}$ respectively are the minimum and maximum values of the stresses in the concrete (with compression or with elongation), emerging from a change only of the multiple repeated load.

$\rho_б$	0,1	0,2	0,3	0,4	0,5	0,6
$K_{\rho_б}$	0,75	0,8	0,85	0 9	0,95	1

In the case of $\rho_b > 0.6$, checking the compressed concrete for durability and checking the elongated concrete for the formation of cracks is not carried out with consideration of the influence of the multiple repeated load.

The calculated resistance of the elongated rod and wire reinforcement, with a calculation for durability of R_a', are figured by multiplying the calculated resistance of the elongated reinforcement R_a, determined according to Table 8, appendix I, by coefficient K_ρ taken according to Table 20 as a function of the characteristic of the stress cycle in the reinforcement.

$$\rho_a = \frac{\sigma_{a.\text{мин}}}{\sigma_{a.\text{макс}}} , \frac{\text{min}}{\text{max}} \qquad (65)$$

where $\sigma_{a.min}$ and $\sigma_{a.max}$ respectively are the maximum and minimum values of stress in the elongated reinforcement, emerging from the change only of the multiply repeated load.

Table 20

Type of reinforcement	Value of the coefficient K_{ρ_a} at ρ_a equal to								
	1	−0,2	0	0,2	0,4	0,7	0,8	0,9	1
Hot-rolled class A-I	0,45	0,70	0,80	0,85	1	1	1	1	1
Same, class A-II	0,40	0,58	0,65	0,72	0,84	1	1	1	1
Same, class A-III	0,31	0,47	0,52	0,57	0,67	1	1	1	1
High-strength reinforcing wires	—	—	—	—	—	0,8	1	1	1
smooth acc. to GOST 7348-63	—	—	—	—	—	0,70	0,85	0,95	1
Same, periodic profile acc. to GOST 8480-63									

The calculation for durability of an elongated reinforcement is not carried out: for hot rolled steel of class A-I at $\rho_a \geqslant 0.4$; for hot-rolled steel of class A-II at $\rho_a \geqslant 0.7$; for hot-rolled steel of class A-III at $\rho_a \geqslant 0.8$; for a highly stable reinforcing wire: with a smooth profile at $\rho_a \geqslant 0.8$; with a periodic profile /irregular profile/ $\rho_a = 1$.

The calculation of the reinforced concrete slabs with an unstressed reinforcement for durability of the concrete of the inclined cross sections is carried out according to condition:

$$\sigma_{\text{г.р.}max} \leqslant R_\text{т}', \qquad (66)$$

where $\sigma_{\Gamma \cdot \rho \cdot max}$ is the main maximum elongation stress in the concrete, kg/cm^2;

R_T' is the calculated resistance of the concrete to the strain with consideration of the influence of the multiply repeated load, kg/cm^2.

For slabs without prestressing, the maximum main elongation stress $\sigma_{\Gamma.\rho}$. max

is equal to the shearing stress τ_{max} at the level of the center of gravity of the complete cross section, determined according to formula

$$\tau_{max} = \frac{Q_{max} S_n}{I b}, \qquad (67)$$

where Q_{max} is the calculated value of the transverse force, kg; S_T is the static moment of the part of the cross section situated above the neutral axis of the full cross section relative to the same axis, cm^3; I is the moment of inertia of the full cross section of the slab relative to its neutral axis, cm^4; b is the width of the concrete of the full cross section of the slab in the level of its center of gravity, cm.

The calculated value of the transverse force Q_{max} is recommended determined according to the formulas for calculating the strip (29) and (32). Moreover, to determine the calculated rigidity of the slab, we introduce the moment of inertia of the full transverse cross section (with calculation of the elongated concrete). In this case, if the slab belongs to the calculated category of infinite slabs, with the determination of the mathematical value of the transverse force we examine the strip of the slab with a width of 1 pog m, and the coefficient of the dynamics is assumed to be equal to 1. If the same slab belongs to the calculated category of the strips (for example gauge slabs of pavements of temporary roads), then the dynamic coefficient with the determination of the mathematical mathematical force when calculating the inclined cross sections for durability is equal to 1.5. The minimum value of the calculated transverse force Q_{min} with the determination of the cycle of main elongation stresses, is taken as equal to zero.

The calculated resistance of the concrete to elongation, with calculation of the influence of multiple repetition of the load R_T' when calculating for the durability of the concrete of inclined cross sections of reinforced concrete slabs without prestressing, is figured by multiplying the calculated resistance of the concrete to elongation, when calculating for the formation of cracks R_T, taken according to Table 6, Appendix 1, by the coefficient $K_{\rho b}$, determined according to Table 19 as a function of the characteristic of the cycle of the main elongation stresses in the concrete:

$$\rho_6 = \frac{\sigma_{r.p.min}}{\sigma_{r.p.max}}. \tag{68}$$

The durability of the concrete of inclined cross sections is considered guaranteed if condition (66) is fulfilled. If this condition is not fulfilled, then it is necessary to conduct the calculation of the of the clamps with consideration of the influence of the repetition of load in accordance with the recommendations of CNiP II-V.1-62.

The calculation for stability of a reinforced concrete prefabricated road slab with a rectangular cross section is carried out according to the condition (Fig. 63):

$$M \leqslant R_u bx\left(h_0 - \frac{x}{2}\right) + R_{a.c}F'_a(h_0 - a'_a), \tag{69}$$

moreover, the position of the neutral axis is determined from the formula

$$R_a F_a - R_{a.c}F'_a = R_u bx. \tag{70}$$

The calculation according to flrmulas (69) and (70) with calculation of the reinforcement situated in the compressed zone can be carried out only with observance of the condition:

$$z_6 \leqslant z_a, \tag{71}$$

where z_a is the distance between the equivalent forces in the reinforcement of the compressed and elongated zones, cm; z_b is the distance between the equivalent forces in the concrete of the compressed zone and in the reinforcement of the elongated zone, cm.

The following designations are made in formulas (69) and (70):

M is the calculated value of the bending moment, kgcm; R_i is the calculated resistance of the concrete to compression at bend, kg/cm^2; b-is the width of the cross section of the compressed zone of the concrete, cm; x is the height of the compressed zone of the concrete cross section, cm; h_0 is the effective height of the cross section, cm; h is the thickness of the slab, cm; α_a is the distance from the center of gravity of the elongated reinforcement up to the most elongated grain of the cross section, cm; $R_{a.c.}$ is the calculated resistance of the compressed reinforcement, kg/cm^2; F_a' is the area of the cross section of the longitudinally unstressed reinforcement situated in the compressed zone of the cross section, cm2; α_a' is the distance from the center of gravity of the compressed reinforcement to the most compressed grain of the cross section, cm; R_a is the calculated resistance of the longitudinally elongated reinforcement, kg/cm^2; F_a is the area of the cross section of the longitudinally unstressed reinforcement in the elongated zone of the cross section, cm^2.

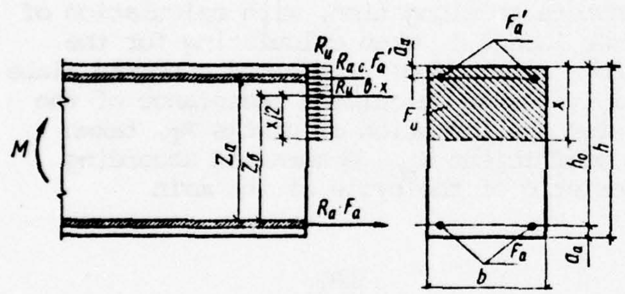


Fig. 63.--Drawing of the disposition of the compressed zone of the concrete and of the forces in a reinforced concrete slab of rectangular transverse cross section (with a calculation for stability).

For slabs of rectangular cross section, the position of the neutral axis, satisfying the sufficient stability of the compressed zone of the concrete, must satisfy the following condition

$$\frac{S_б}{S_0} \leqslant \zeta, \qquad (72)$$

where ζ is the coefficient taken according to Table 21 as a function of the planned concrete brand;

S_b is the static moment of the area of the compressed zone of the concrete relative to the axis normal to the plane of effect of the bending moment and passing through the point of application of the equivalent force in the longitudinal elongated reinforcement, cm^3; S_0 is the static moment of the working cross section of the concrete relative to the axis, normal to the plane of action of the bending moment and passing through the point of application of the equivalent forces in a longitudinally elongated reinforcement, cm^3.

Table 21

Planned brand of cement according to compression, kg/cm^2	400 and lower	500	600
ζ	0.8	0.7	0.65

In case condition (71) is observed, the check for stability of a slab of rectangular cross section is recommended to be carried out as follows. Depending on the value of the relative height of the compressed zone of the concrete, a = x/h_0 is calculated according to the formula:

$$\alpha = \frac{R_a F_a - R_{a.c} F'_a}{R_u b h_0}; \qquad (73)$$

a) with

$$\alpha_{max} > \alpha \geqslant \frac{2a'_a}{h_0},$$

where α_{max} is the coefficient used according to table 23; α_a' is the distance from the compressed edge of the slab cross section to the equivalent forces in the reinforcement situated in the compressed zone of the cross section, cm; the stability of the cross section of checked according to condition

$$M \leqslant A_0 R_u b h_0^2 + R_{a.c} F'_{a.c} (h_0 - a'_a), \qquad (74)$$

where A_0 is the coefficient determined according to Table 22 as a function of the value of α.

Table 22

α	γ	A_0	α	γ	A_0	α	γ	A_0
0,01	0,995	0,01	0,19	0,905	0,172	0,37	0,815	0,301
0,02	0,99	0,02	0,20	0,9	0,18	0,38	0,81	0,308
0,03	0,985	0,03	0,21	0,895	0,188	0,39	0,805	0,314
0,04	0,98	0,039	0,22	0,89	0,196	0,40	0,8	0,32
0,05	0,975	0,049	0,23	0,885	0,203	0,41	0,795	0,326
0,06	0,97	0,058	0,24	0,88	0,211	0,42	0,79	0,332
0,07	0,965	0,067	0,25	0,875	0,219	0,43	0,785	0,337
0,08	0,96	0,077	0,26	0,87	0,226	0,44	0,78	0,343
0,09	0,955	0,086	0,27	0,865	0,234	0,45	0,775	0,349
0,10	0,95	0,095	0,28	0,86	0,241	0,46	0,77	0,354
0,11	0,945	0,104	0,29	0,855	0,248	0,47	0,765	0,359
0,12	0,94	0,113	0,30	0,85	0,255	0,48	0,76	0,365
0,13	0,935	0,121	0,31	0,845	0,262	0,49	0,755	0,37
0,14	0,93	0,13	0,32	0,84	0,269	0,50	0,75	0,375
0,15	0,925	0,139	0,33	0,835	0,275	0,51	0,745	0,38
0,16	0,92	0,147	0,34	0,83	0,282	0,52	0,74	0,385
0,17	0,915	0,155	0,35	0,825	0,289	0,53	0,735	0,39
0,18	0,91	0,164	0,36	0,82	0,295	0,54	0,73	0,391
						0,55	0,725	0,4

The coefficients $\alpha(\alpha')$, $A_0(A_0')$ and $\gamma(\gamma')$, listed in Table 22, for the bending elements of the rectangular cross section are calculated according to the following formulas

$$\alpha = \frac{R_a F_a + R_a F_н - R_{a.c} F_a' - \sigma_c' F_н}{R_и b h_0}; \quad A_0' = \frac{M + m_т \sigma_0' F_н (h_0 - a_н')}{R_и b h_0^2};$$

$$\alpha' = \frac{R_a F_a + R_a F_н + m_т \sigma_0 F_н'}{R_и b h_0}; \quad A_0 = \alpha(1 - 0{,}5\alpha);$$

$$A_0 = \frac{M - R_{a.c} F_a' (h_0 - a_a') - \sigma_c' F_н' (h_0 - a_н')}{R_и b h_0^2}; \quad \gamma = 1 - 0{,}5\alpha;$$

b) in the case of $\alpha \geqslant \alpha_{max}$

the stability of the cross section is checked from condition (74) taking

$$A_0 = A_{0.max}$$

The coefficients α_{max} and $A_{0\ max}$ are determined according to Table 23.

Table 23

Concrete brand	$A_{0\ max}$	α_{max}
400 and lower	0.4	0.55
500	0.35	0.45
600	0.325	0.41

Note: If the calculation is carried out according to the cubic stability of the concrete, which corresponds to the brand shown in the table, then the values A_{0max} is determined according to interpolation, and the value of α_{max} is calculated according to the formula $\alpha_{max} = 1 - \sqrt{1-2A_{0\ max}}$ or it is also determined according to interpolation;

c) in the case of $\alpha < 2\alpha'_a/h_0$

the stability of the slab cross section is checked from the condition

$$M \leqslant R_a F_a z_a, \quad (75)$$

where $z_a = h_0 - \alpha'_a$.

If moreover $\alpha' < \frac{2a_a'}{h_0}$,

where α' is the relative height of the compressed zone of the concrete without consideration of the unstressed reinforcement situated in the compressed zone of the slab cross section. The stability of the cross section may be checked without calculating the unstressed reinforcement situated in the compressed zone of the slab cross section from the condition

$$M \leqslant R_a F_a \gamma' h_0, \quad (76)$$

where γ' is the coefficient determined according to Table 22 as a function of the value α', calculated according to the formula

$$\alpha' = \frac{R_a F_a'}{R_{\text{и}} b h_0}. \qquad (77)$$

The value of the limit bending moment M_{pr}, which may take up the cross section of the slab with the given reinforcement, is determined according to one of the expressions (74), (75) or (76) as a function of the value of α.

If the condition (71) is not observed, then checking the stability of the slab of rectangular cross section is carried out in the same way as for the cross section with an identical reinforcement from the condition that

$$M \leqslant R_a F_a \gamma h_0. \qquad (78)$$

or from the condition

$$M \leqslant A_0 R_{\text{и}} b h_0^2. \qquad (79)$$

The coefficients γ and A_0 are determined according to Table 22 as a function of

$$\alpha = \frac{R_a F_a}{R_{\text{и}} b h_0}. \qquad (80)$$

Where $\alpha \geq \alpha_{max}$ the stability of the slab cross section is checked from the condition (79), in the case of $A_0 = A_{0max}$. The coefficients α_{max} and A_{0max} are determined according to Table 23.

In the case of relatively small values $\alpha (\alpha<0.10)$, the stability of the slab cross section is recommended to be checked from condition (78).

The value of the limit bending moment M_{pr} which may take up the cross section with a given reinforcement, is taken as equal to the right part of inequality (78) or (79) as a function of the value of α.

It is not recommended to use cross sections with a double reinforcement, not satisfying the condition

$$M \leqslant R_{\text{и}} S_0. \qquad (81)$$

The determination of the required area of a longitudinal, unstressed reinforcement, situated in the compressed zone, with given dimensions of the rectangular cross section is carried out according to formula

$$F_a' = \frac{M - A_{0.\text{макс}} R_{\text{и}} b h_0^2}{R_{a.c}(h_0 - a_a')}, \qquad (82)$$

where A_{0max} is determined according to Table 23.

If, with the calculation of formula (82), the value of F_a' is obtained equal to zero or is negative, then the reinforcements taking up the compressive forces are not required according to the calculation for stability. In this case, it is placed either according to design considerations and, as a rule, it is not

taken into account in the calculation, or from the calculation on the moment of the other sign (in the case of another scheme of the loads), and then it is recommended to take it into account when selecting the cross section of the elongated reinforcement.

The determination of the required area of the cross section of the longitudinal reinforcement situated in the elongated zone with given dimensions of the rectangular slab cross section is carried out from the condition

$$R_a F_a = N_a.$$

The force N_a, which must be taken up by the elongated reinforcement, is determined as a function of the value of the relative height of the compressed zone of the concrete $\alpha = x/h_0$. In this case, α is determined according to Table 22 as a function of the value

$$A_0 = \frac{M - R_{a.c} F'_a (h_0 - a'_a)}{R_u b h_0^2}. \quad (83)$$

Moreover, it is necessary to satisfy the condition $A_0 \leqslant A_{0max}$ (see Tab;e 23).

The determination of the force N_a is carried out as follows:

a) in the case of $\alpha \geqslant 2a'_a/h_0$, the force N_a is determined according to the formula

$$N_a = \alpha R_u b h_0 + R_{a.c} F'_a; \quad (84)$$

b) in the case of $\alpha = 2a'_a/h_0$, the force N_a is determined according to the formula

$$N_a = \frac{M}{z_a},$$

where $z_a = h_0 - \alpha'_a$.

If moreover

$$\alpha' < \frac{2a'_a}{h_0},$$

where α' is the relative height of the compressed zone of the concrete without consideration of the unstressed reinforcement situated in the compressed zone of the slab cross section, then N_a may be smaller, proceeding on the basis of the formula

$$N_a = \frac{M}{\gamma' h_0}, \quad (85)$$

where γ' is determined according to Table 22 as a function of the value

$$A_0 = \frac{M}{R_u b h_0^2}. \quad (86)$$

If according to the calculation an unstressed reinforcement is required in the compressed zone of the slab cross section, and the area of the cross section of this reinforcement is taken to be close to its theoretical value F_a', obtained according to formula (82), the force N_a is determined at the theoretical value F_a' according to formula

$$N_a = \alpha_{\text{макс}} R_и b h_0^2 + R_{a.c} F_a. \qquad (87)$$

For the rectangular cross section with the same reinforcement, the force N_a is determined according to the formula

$$N_a = \alpha R_u b h_0 \tag{88}$$

or according to the formula

$$N_a = \frac{M}{\gamma h_0}, \tag{89}$$

where α and γ_0 are determined according to Table 22 as a function of the value of A_0, calculated according to the formula

$$A_0 = \frac{M}{R_u b h_0^2}. \tag{90}$$

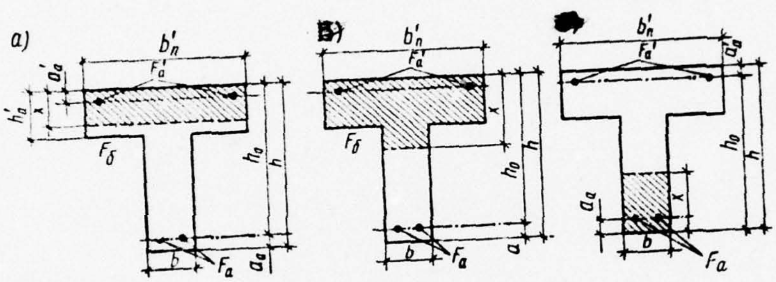


Fig. 64.—Scheme of the disposition of the compressed zone of concrete in a reinforced concrete slab of a T transverse cross section (with a calculation for stability): a - neutral axis passes into the flange of the beam (compressed zone—part of the beam); b-neutral axis passes into the rib (compressed zone-flange of the beam and part of the rib); c- neutral axis passes into the rib (compressed zone—part of the rib).

Moreover, it is necessary to satisfy the condition $A_0 \leqslant A_{0max}$ (see Table 23). If this condition is not satisfied, then it is necessary to increase the cross section, raise the brand of concrete or or instal an unstressed reinforcement in the compressed zone.

With values $A_0 < 0.1$, it is recommended to determine the force N_a according to formula (89).

The calculation for stability of the reinforced concrete road slab, the cross section of which has a beam flange in the compressed zone (T-shaped), is carried out as follows:

a) if the neutral axis passes into the flange of the beam (Fig. 64,a), i.e.

$$R_a F_a \leqslant R_u b'_n h'_n + R_{a.c} F'_a, \tag{91}$$

then the calculation is carried out as for slabs of a rectangular cross section with the width b_π'.

For cross sections, corresponding to the values of Table 24, lying below the solid lines for a given brand of concrete, in which the neutral axis, responsible for the sufficient stability of the concrete in the compressed zone, is situated in the flange of the beam, in any case the calculation is carried out as for

the rectangular cross section with a width b_{Π}', assuming A_0 to be not larger than

$$A_0 = \frac{1+2{,}5A_{\text{сп}}}{b'_{\text{п}}/b}.$$

For slabs with a T cross section or leading to a T and having the flange of a beam in the compressed zone with disposition of the neutral axis in the flange of the feam, the check for sufficient stability of the compressed zone is carried out according to the following expression

$$\frac{S_{\text{б.п}}}{S_{\text{о.реб}} + S_{\text{сп}}} < \zeta, \qquad (92)$$

where ζ is taken according to Table 21;

b) if the neutral axis passes into the rib (Fig. 64,b), i.e. does not fulfill condition (91), then the calculation is carried out according to condition

$$M \leqslant R_{\text{и}}bx\left(h_0 - \frac{x}{2}\right) + R_{\text{пр}}\,(b'_{\text{п}} - b)\left(h_0 - \frac{h'_{\text{п}}}{2}\right) h'_{\text{п}} + R_{\text{а.с}}F'_{\text{а}}\,(h_0 - a'_{\text{а}}). \qquad (93)$$

Moreover, the position of the neutral axis is determined from the formula

$$R_{\text{а}}F_{\text{а}} = R_{\text{и}}bx + R_{\text{пр}}\,(b'_{\text{п}} - b)\,h'_{\text{п}} + R_{\text{а.с}}F'_{\text{а}}. \qquad (94)$$

For slabs of a T cross section or leading to a T, having the flange of a beam in the compressed zone, with disposition of the neutral axis in the rib, checking for the condition of sufficient stability of the compressed zone is (72) carried out as for the rectangular cross section without considering the projections of the beam flange, i.e.

$$\frac{S_{\text{б.реб}}}{S_{\text{о.реб}}} \leqslant \zeta, \qquad (95)$$

where ζ is taken according to Table 21.

The projections of the beam flange, situated in the elongated zone, are not taken into account in all cases when checking condition (72).

In this case, it is recommended to check for stability of the slab cross section from condition

$$M \leqslant (A_0 + A_{\text{сп}})\,R_{\text{и}}bh_0^2 + R_{\text{а.с}}F'_{\text{а}}\,(h_0 - a'_{\text{а}}). \qquad (96)$$

A_0 is determined according to Table 22 as a function of the value of the relative height of the compressed zone of the concrete $\alpha = x/h_0$, calculated according to the formula

$$\alpha = \alpha_1 - \alpha_{\text{сп}}, \qquad (97)$$

where

$$\alpha_1 = \frac{R_{\text{а}}F_{\text{а}} - R_{\text{а.с}}F'_{\text{а}}}{R_{\text{и}}bh_0}, \qquad (98)$$

where A_{CB} and α_{CB} are determined according to Table 24.

If $\alpha < \alpha_{max}$, , then the stability of the cross section is checked from condition (96), where $A_0 = A_{0max}$; α_{max} and A_{0max} are determined according to Table 23.

In the case where $\alpha < \frac{a'_a}{h_0}$

the stability of the slab cross section is checked in the same way as for the rectangular cross section (in the case where $\alpha < 2\alpha'_a/h_0$).

The value of the limit bending moment M_{pr}, which may take up the cross section with the given reinforcement, is determined from the equation (96).

The width of the projections of the compressed beam flange on each side of the rib, introduced into the calculation, with the relationship $h_\pi' \geq 0.1$ h, must not exceed $6h_\pi'$.

The determination of the required area of the cross section of the longitudinal unstressed reinforcement, situated in the compressed zone of the slab cross section, at given dimensions of the T cross section, is carried out according to the formula

$$F'_a = \frac{M - (A_{0.\text{макс}} + A_{\text{сп}}) R_{\text{и}} b h_0^2}{R_{a.c} (h_0 - a'_a)}, \qquad (99)$$

where A_{0max} and A_{CB} are determined according to Tables 23 and 24 respectively.

In the elements from concrete of brands higher than 400, for the cross sections of corresponding values of A_{CB}, lying in Table 24 below the heavy line for a given brand of concrete, the value of A_{CB} in formula (99) is multiplied by the coefficient 2.5 A_{0max}.

The determination of the required amount of longitudinal reinforcements situated in the elongated zone, with given dimensions of the T-cross section of the slab is carried out from the condition

$$R_a F_a = N_a.$$

The force N_a, which must be taken up by the elongated reinforcement, is determined as a function of the neutral axis in the cross section:

a) where

$$M \leqslant R_{\text{и}} b'_{\text{п}} h'_{\text{п}} (h_0 - 0{,}5 h'_{\text{п}}) + R_{a.c} F'_a (h_0 - a'_a), \qquad (100)$$

i.e. when the neutral line is located in the limits of the compressed beam flange, the force N_a is determined like the rectangular cross section with width b_{Π}'. Moreover, for cross sections corresponding to values of the coefficients of Table 24, lying below the heavy line (for a given brand of concrete), it is necessary to satisfy the condition

$$A_0 \leqslant \frac{A_{0\,\text{макс}}(1+2{,}5A_{\text{св}})}{b_{\text{п}}'/b};$$

b) where

$$M > R_{\text{и}} b_{\text{п}}' h_{\text{п}}' (h_0 - 0{,}5h_{\text{п}}') + R_{\text{а.с}} F_{\text{а}}' (h_0 - a_{\text{а}}'), \qquad (101)$$

i.e. when the neutral line is located in the limits of the rib, the force N_a is determined according to formula

$$N_{\text{а}} = (\alpha + \alpha_{\text{св}}) R_{\text{и}} b h_0 + R_{\text{а.с}} F_{\text{а}}'. \qquad (102)$$

Table 24

$\frac{b'_n}{b}$	Coeff-icients	Values $A_{cв}$ and $\alpha_{cв}$ with ratios h'_n/h_0																
		0,1	0,11	0,12	0,13	0,14	0,15	0,16	0,17	0,18	0,19	0,2	0,21	0,22	0,23	0,24	0,25	
1,5	$A_{cв}$	0,038	0,042	0 045	0,049	0,052	0,056	0,059	0,06	0,066	0,069	0,07	0,08	0,08	0,08	0,08	0,09	
	$\alpha_{cв}$	0,40	0,044	0,048	0,05	0,056	0,06	0,06	0,07	0,072	0,076	0,08	0,08	0,09	0,09	0,10	0,01	
2	$A_{cв}$	0,076	0,08	0,1	0,1	0,104	0,11	0,12	0,12	0,13	0,14	0,14	0,15	0,16	0,16	0,17	0,18	
	$\alpha_{cв}$	0,08	0,088	0,09	0,1	0,112	0,12	0,13	0,14	0,14	0,15	0,16	0,17	0,18	0,18	0,19	0,2	
2,5	$A_{cв}$	0,114	0,12	0,14	0,15	0,16	0,17	0,18	0,19	0,2	0,21	0,22	0,23	0,24	0,24	0,25	0,26	For conceete brand 600
	$\alpha_{cв}$	0,12	0,13	0,14	0,16	0,17	0,18	0,19	0,2	0,22	0,23	0,24	0,25	0,26	0,28	0,29	0,3	
3	$A_{cв}$	0,152	0,17	0,18	0,19	0,21	0,22	0,24	0,25	0,26	0,28	0,29	0,3	0,31	0,33	0,34	0,35	
	$\alpha_{cв}$	0,16	0,18	0,19	0,21	0,22	0,24	0,26	0,27	0 29	0,3	0,32	0,34	0,35	0,37	0,38	0,4	
3,5	$A_{cв}$	0,19	0,21	0,23	0,24	0,26	0,28	0,29	0,31	0,33	0,34	0,36	0,38	0,39	0,41	0,42	0,44	For concrete brand 500
	$\alpha_{cв}$	0,2	0,22	0,24	0,26	0,28	0,3	0,32	0,34	0,36	0,38	0,4	0,42	0,44	0,46	0,48	0,5	
4	$A_{cв}$	0,23	0,25	0,27	0,29	0,31	0,33	0,35	0,37	0,39	0,41	0,43	0,45	0,47	0,49	0,51	0,53	
	$\alpha_{cв}$	0 24	0,26	0,29	0,31	0,34	0,36	0,38	0,41	0,43	0,46	0,48	0,5	0,53	0,55	0,58	0,6	
4,5	$A_{cв}$	0,27	0,29	0,32	0,34	0,36	0,39	0,41	0,44	0,46	0,48	0,5	0,53	0,55	0,57	0,59	0,61	
	$\alpha_{cв}$	0,28	0,31	0,34	0,36	0,39	0,42	0,45	0,48	0,5	0,53	0,56	0,59	0,62	0,64	0,67	0,7	
5	$A_{cв}$	0,3	0,33	0,36	0,39	0,42	0,44	0,47	0,5	0,52	0,55	0,58	0,6	0,63	0,65	0,68	0,7	For concrete brand 400
	$\alpha_{cв}$	0,32	0,35	0,38	0,42	0,45	0,18	0,51	0,54	0,58	0,61	0,64	0,67	0,7	0,74	0,77	0,8	
5,5	$A_{cв}$	0,34	0,37	0,41	0,44	0,47	0,5	0,53	0,56	0,59	0,62	0,65	0,68	0,71	0,73	0,76	0.79	
	$\alpha_{cв}$	0,36	0,4	0,43	0,47	0,5	0,54	0,58	0,61	0,65	0,68	0,72	0,76	0,79	0,83	0,86	0,9	

Appendix to Table 24

$\frac{b'_n}{b}$	Coefficients	Values A_{cn} and α_{cn} with ratios h'_n/h_0															
		0,1	0,11	0,12	0,13	0,14	0,15	0,16	0,17	0,18	0,19	0,2	0,21	0,22	0,23	0,24	0,25
6	A_{cn} α_{cn}	0,38 0,4	0,42 0,44	0,45 0,48	0,49 0,52	0,52 0,56	0,56 0,6	0,59 0,64	0,62 0,68	0,66 0,72	0,69 0,76	0,72 0,8	0,75 0,84	0,78 0,88	0,81 0,92	0,85 0,96	0,88 1
6,5	A_{cn} α_{cn}	0,42 0,44	0,46 0,48	0,5 0,53	0,54 0,57	0,57 0,62	0,61 0,66	0,65 0,7	0,69 0,75	0,72 0,79	0,76 0,84	0,79 0,88	0,83 0,92	0,86 0,97	0,91 1,01	0,93 1,06	0,96 1,1
7	A_{cn} α_{cn}	0,46 0,48	0,5 0,53	0,54 0,58	0,58 0,62	0,63 0,67	0,67 0,72	0,71 0,77	0,75 0,82	0,79 0,86	0,83 0,91	0,86 0,96	0,9 1,01	0,94 1,06	0,99 1,10	1,01 1,15	1,05 1,2
7,5 For concrete brand 600	A_{cn} α_{cn}	0,49 0,52	0,54 0,57	0,58 0,62	0,63 0,68	0,68 0,73	0,72 0,78	0,77 0,83	0,81 0,88	0,85 0,94	0,9 0,99	0,94 1,04	0,98 1,09	1,02 1,14	1,06 1,2	1,1 1,25	1,14 1,3
8	A_{cn} α_{cn}	0,53 0,56	0,58 0,62	0,63 0,67	0,68 0,73	0,73 0,78	0,78 0,84	0,83 0,9	0,89 0,95	0,92 1,01	0,97 1,06	1,01 1,12	1,05 1,18	1,1 1,23	1,14 1,29	1,18 1,34	1,23 1,4
9	A_{cn} α_{cn}	0,61 0,64	0,67 0,7	0,72 0,77	0,78 0,83	0,83 0,9	0,89 0,95	0,94 1,02	1 1,09	1,05 1,15	1,1 1,22	1,15 1,28	1,2 1,34	1,25 1,41	1,3 1,47	1,35 1,54	1,4 1,6

for concrete brand 500

Appendix to Table 24

b'_n / b	Coefficients	Values $A_{cв}$ and $\alpha_{cв}$ with ratios h'_n/h_0: 0,1	0,11	0,12	0,13	0,14	0,15	0,16	0,17	0,18	0,19	0,2	0,21	0,22	0,23	0,24	0,25
10 For concrete brand 500	$A_{cв}$ $\alpha_{cв}$	0,68 0,72	0,75 0,79	0,81 0,86	0,88 0,94	0,94 1,01	0,99 1,08	1,06 1,15	1,12 1,22	1,18 1,3	1,24 1,37	1,3 1,44	1,35 1,51	1,41 1,58	1,47 1,66	1,52 1,73	1,58 1,8
11	$A_{cв}$ $\alpha_{cв}$	0,76 0,8	0,83 0,88	0,9 0,96	0,97 1,04	1,08 1,12	1,11 1,2	1,18 1,28	1,25 1,36	1,31 1,44	1,38 1,52	1,44 1,6	1,5 1,68	1,57 1,76	1,63 1,84	1,69 1,92	1,75 2
12	$A_{cв}$ $\alpha_{cв}$	0,84 0,88	0,92 0,97	0,99 1,06	1,07 1,14	1,14 1,23	1,22 1,32	1,3 1,41	1,37 1,5	1,44 1,58	1,51 1,67	1,58 1,76	1,65 1,85	1,72 1,94	1,79 2,02	1,86 1,11	1,93 2,2
13	$A_{cв}$ $\alpha_{cв}$	0,91 0,96	1 1,06	1,09 1,15	1,17 1,25	1,25 1,34	1,33 1,44	1,42 1,54	1,5 1,63	1,57 1,73	1,65 1,82	1,73 1,92	1,8 2,02	1,88 2,11	1,95 2,21	2,03 2,3	2,1 2,4
14	$A_{cв}$ $\alpha_{cв}$	0,99 1,04	1,08 1,14	1,17 1,25	1,26 1,35	1,36 1,46	1,44 1,56	1,53 1,66	1,64 1,77	1,7 1,87	1,79 1,98	1,87 2,08	1,95 1,18	2,04 2,29	2,11 2,39	2,19 2,5	2,27 2,6
15	$A_{cв}$ $\alpha_{cв}$	1,07 1,12	1,16 1,23	1,26 1,34	1,36 1,46	1,46 1,57	1,55 1,68	1,65 1,79	1,74 1,9	1,83 2,02	1,93 2,13	2,02 2,24	2,11 2,35	2,19 2,46	2,28 2,58	2,36 2,69	2,45 2,8

For concrete brand 400 and lower

$$A_{cв} = 0,8 \frac{(b'_n - b)h'_n}{bh_0}\left(1 - 0,5\frac{h'_n}{h_0}\right)$$

$$\alpha_{cв} = 0,8 \frac{(b'_n - b)h'_n}{bh_0}$$

The relative height of a compressed zone of concrete $\alpha = x/h_0$ is determined according to Table 22 as a function of the value

$$A_0 = A_{01} - A_{cB}, \qquad (103)$$

where

$$A_{01} = \frac{M - R_{a.c} F'_a (h_0 - a'_a)}{R_u b h_0^2}, \qquad (104)$$

where A_{CB} and α_{CB} are determined according to Table 24.

Moreover, it is necessary to satisfy the condition

$$A_0 \leqslant A_{0.\text{макс}}.$$

The value of A_{0max} is determined according to Table 22. In the case $\alpha < \frac{2a'_a}{h_0}$ the force N_a is determined in the same way as for the rectangular cross section.

(where $\alpha < 2a'_a/h_0$.

For cross sections correspond to the values of the coefficients of Table 24, lying below the solid line (for a given brand of concrete), the neutral axis, responding to the sufficient stability of the compressed zone of the concrete, is situated in the beam flange, thus the calculation of such cross sections is carried out independent of condition (100), as for the rectangular cross section with a width b_π, (width of the beam flange).

If the flange of the beam with a T cross section is located in the elongated zone (Fig. 64,c), for example in the case of calculating the ribbed slab for a negative bending moment, the calculation of the slab for stability is carried out as for the rectangular cross section with a calculated width equal to the width of rib b.

The width of the disclosure of cracks a_T in reinforced concrete slabs with an unstressed reinforcement is determined according to the formula

$$a_T = \psi \frac{\sigma_a}{E_a} l_T, \qquad (105)$$

where l_T is the distance between the cracks, cm; σ_a is the stress in the elongated reinforcement, kg/cm^2 determined according to the formula

$$\sigma_a = \frac{M}{z_1 F_a}, \qquad (106)$$

where z_1 is the shoulder of the internal pair of forces, equal to

$$z_1 = h_0 \left[1 - \frac{\frac{h'_n}{h_0}\gamma' + \xi^2}{2(\gamma' + \xi)} \right], \qquad (107)$$

$$\gamma' = \frac{(b'_n - b)\, h'_n + \frac{n}{\nu} F_a}{b h_0}, \qquad (108)$$

where ν is the ratio of the elastic part of deformation of the edge of the compressed grain to its full deformation.

For bent designs, made without prestressing, with the short-term effect of load $\nu = 0.5$, the relative height of the compressed zone of the concrete is

$$\xi = \frac{1}{1{,}8 + \dfrac{1 + 5(L_T + T)}{10\mu_a n}}, \tag{109}$$

where

$$L_T = \frac{M}{R_{\text{п}}^{\text{н}} b h_0^2}, \tag{110}$$

$$T = \gamma'\left(1 - \frac{h'_{\text{п}}}{2h_0}\right), \tag{111}$$

$$\mu_a = \frac{F_a}{b h_0}. \tag{112}$$

For rectangular cross sections, having a reinforcement placed in the compressed zone, the value $2\alpha_a'$ is substituted in formula (111) instead of the value h_π'.

If the height of the compressed zone of the concrete x is less than the thickness of the beam flange h_π', situated in the compressed zone, i.e.

$$\xi = \frac{h'_{\text{п}}}{h_0}, \tag{113}$$

then the values ξ and z_1 should be determined as for the rectangular cross section with a width b_π', taking

$$\gamma' = 0;\ \mu_a = \frac{F_a}{b'_{\text{п}} h_0};\ L_T = \frac{M}{R_{\text{п}}^{\text{н}} b'_{\text{п}} h_0^2}.$$

If we observe the condition

$$\xi < \frac{2a'_a}{h_0}, \tag{114}$$

then the values γ', ξ, z_1 should be determined without calculating the compressed reinforcement.

In case of the effect of multiple, repeated load, the coefficient ψ in formula (105) may be assumed equal to 1.

The distance between the cracks l_T is determined according to the formula

$$l_T = K_1 n u_a \eta, \tag{115}$$

where

$$u_a = \frac{F_a}{S}, \tag{116}$$

here S is the perimeter of the reinforcement cross section, cm; K_1 is the coefficient determined according to the formula

$$K_1 = \frac{W_T}{F_a z_1 \eta} - 2, \qquad (117)$$

where W_T is the resistance moment of the cross section, determined with consideration of the seinforcement; η is the coefficient depending on the type of longitudinal, elongated reinforcement, taken as equal: for rods of periodic profile $\eta = 0.7$; for smooth hot-rolled rods $\eta = 1$; for ordinary reinforcing wires, used in frameworks and screens, $\eta = 1.25$,

The perimeter of the cross section of the rods of periodical profile are taken to be equal to the length of the circumference, conforming to the hominal diameter, without calculating the projections and the ribs.

The resistance moment of the cross section W_T in formula (117) is determined according to the following expression:

$$W_{т} = \gamma W_0, \qquad (118)$$

where W_0 is the resistance moment of the reduced cross section, cm^3; γ is the coefficienteqqual to 1.75 for the rectangular cross section; equal to 1.75 for the T cross section with a flange situated in the compressed zone; for the T cross section with a flange situated in the elongated zone, in the case of $b_\pi/b \leqslant$ independent of the ratio $h_\pi/h \geqslant 1.75$; in the case of $b_\pi/b>2$ and $h_\pi/h \geqslant 0.2$-1.75; in the case of $b_\pi/b>2$ and $h_\pi/h<0.2$-1.5.

The width of crack discovery in the reinforced concrete road slabs (without prestressing) is considered permissible if it does not exceed 0.4 mm.

11. Method for Calculating Prestressed Reinforced Concrete Slabs for Durability

The sequence of the calculation of prestressed reinforced concrete slabs is as follows.

First, the calculation is carried out for the durability of normal cross sections which in these designs comes down to checking the possibility of the formation of cracks with consideration of the influence of the repeated effect of load. This check is expressed by the condition that the maximum value of elongation stresses $\sigma_{b.p.}$ in the extreme grain of the elongated concrete must not exceed the calculated resistance of the concrete to elongation R_T' (see 10, Chapter II):

$$\sigma_{б.р} \leqslant R_{т}'. \qquad (119)$$

In addition, the edge compressive stress in the concrete σ_b must not exceed the calculated resistance of the concrete to compression at bend R_i' (see § 10, Chapter II).

$$\sigma_б \leqslant R_и', \qquad (120)$$

and the maximum stress in the longitudinally elongated reinforcement σ_a must not exceed the values of calculated resistance of the reinforcement Ra'.

$$\sigma_а \leqslant R_а'. \qquad (121)$$

The normal stresses in the concrete and in the reinforcement with calculation of the prestressed slab for durability are calculated according to the geometric characteristics of its full cross section (in planning the elastic work). The coefficient of reduction n in this case is equal to the ratio of the elasticity modulus of the reinforcement to the modulus of elasticity of the concrete and should be taken according to Table 25.

Table 25

Обозначения	Марки бетона						
	100	150	200	300	400	500	600
Горячекатаная сталь классов А-I, А-II, А-IIIв	11	9,1	7,9	6,7	6	5,5	5,2
Горячекатаная сталь классов А-III, А-IIIв, А-IV	10,5	8,7	7,5	6,3	5,7	5,3	5,0
Проволока обыкновенная и высокопрочная, пучки и пряди	9,5	7,8	6,8	5,7	5,1	4,7	4,5

In connection with the relatively small percentage of reinforcements, and also in connection with the fact that with calculation of the slabs of prefabricated pavements, lying on an elastic base, the effect of gravity is not taken into account, when calculating the geometric characteristics of the cross section, the area of the reinforcement in the cross section is neglected.

The stresses in the concrete and in the reinforcement are calculated from the joint force of prestress and of automobile load.

The stresses of the cycle in the extreme lower grain of the concrete cross section are determined according to the following formulas:

a) from the effect of the positive bending moment M_{max}

$$\sigma_{б.макс} = \frac{M_{макс}}{I} y_н, \qquad (122)$$

where I is the moment of inertia of the weakest full cross section of the slab, cm^4; y_H is the distance from the neutral axis to the extreme lower grain of the cross section, cm;

b) from the effect of the negative bending moment

$$\sigma_{б.мин} = \frac{M_{мин}}{I} y_н; \qquad (123)$$

c) from the force of prestressing

$$\sigma_б = \frac{\sigma_{ан}(F_н + F'_н)}{F_б} + \frac{(F_н e_2 - F'_н e_1)\,\sigma_{ан}}{W_н}, \qquad (124)$$

where $\sigma_{a\pi}$ is the preliminary stress in the reinforcement with calculation of all losses of preliminary stress, kg/cm^2; F_H is the area of the lower prestressed reinforcement, cm^2; F_H' is the area of the upper prestressed reinforcement, cm^2; F_b is the area of the concrete of the slab cross section, cm^2, e_1 is the distance (eccentricity) between the center of gravity of the cross section and the center of gravity of the upper prestressed reinforcement, cm; e_2 is the distance (eccentricity) between the center of gravity of the lower prestressed reinforcement, cm; W_H is the resistance moment of the cross section relative to the extreme lower grain, cm^3.

The stresses of the cycle in the extreme upper grain of the concrete cross section are determined according to formulas (122)-(124) substituting y_H for y_B, W_H for W_B and the plus sign before the second component of the right part of equation (124) on the inverse, wgere y_B is the distance from the neutral axis of the cross section to the extreme upper grain of the cross section, cm; W_B is the resistance moment of the cross section relative to the extreme upper grain, cm^3.

The characteristic of the stress cycle in the extreme lower grain of the concrete equals

$$\rho_б = \frac{\sigma_б - \sigma_{б.макс}}{\sigma_б + \sigma_{б.мин}}. \qquad (125)$$

The characteristics of the stress cycle in the extreme upper grain of the concrete equals

$$\rho_б = \frac{\sigma_б - \sigma_{б.мин}}{\sigma_б + \sigma_{б.макс}}. \qquad (126)$$

In accordance with the obtained values of the cycle characteristic ρ_b according to Table 19, we determine the value $K_{\rho b}$ and the values R_T' and R_i' corresponding to it.

The conditions of durability of the concrete of normal cross sections of the slab are as follows:
for the extreme lower grain

$$\sigma_б + \sigma_{б.мин} \leqslant R_и', \qquad (127)$$

$$\sigma_б - \sigma_{б.макс} \leqslant R_т', \qquad (128)$$

for the extreme upper grain

$$\sigma_б + \sigma_{б.макс} \leqslant R_и', \qquad (129)$$

$$\sigma_б - \sigma_{б.мин} \leqslant R_т'. \qquad (130)$$

The stresses in the lower prestressed reinforcement are determined according to the formulas:
a) from the effect of the positive bending moment

$$\sigma_{а.макс} = n \frac{M_{макс}}{I} e_2; \qquad (131)$$

b) from the effect of the negative bending moment

$$\sigma_{\text{а.мин}} = n \frac{M_{\text{мин}}}{I} e_2; \qquad (132)$$

c) prestressing with regard to loss $\sigma_{a\pi}$; the method for determining the value $\sigma_{a\pi}$ is presented in a later paragraph.

The stresses in the upper prestressed reinforcement are determined according to formulas (131) and (131) substituting e_2 for e_1.

The characteristics of **the stress cycle:** in the lower reinforcement

$$\rho_a = \frac{\sigma_{a\pi} - \sigma_{a.\text{мин}}}{\sigma_{a\pi} + \sigma_{a.\text{макс}}}; \tag{133}$$

in the upper reinforcement

$$\rho_a = \frac{\sigma_{a\pi} - \sigma_{a.\text{макс}}}{\sigma_{a\pi} + \sigma_{a.\text{мин}}}. \tag{134}$$

In accordance with the cyaracteristics of the cycle ρ_a, the value of $K_{\rho a}$ and the values corresponding to it R_a' are determined according to Table 20.

The condition of durability of the **prestressed reinforcement:**

of the lower $-\sigma_{a\pi} + \sigma_{a.\text{макс}} \leqslant R_a'$; (135)

of the upper $-\sigma_{a\pi} + \sigma_{a.\text{мин}} \leqslant R_a'$. (136)

The values (of preliminary) stresses (up to compression) of the concrete in the upper and lower prestressed reinforcement, taken in the calculations, must be: not more than 0.7 R_a^H for wire reinforcements, but not less than 0.4 R_a^H; for rod reinforcements not more than 0.9 R_a^H.

Usually, in planning, stresses are taken equal to the ones indicated for the upper limits.

Intthe calculation for the formation of cracks of the preliminary compressed zone of a normal cross section, a preliminarily elongated stress is introduced into the reinforcement the coefficient of accuracy of the prestressed reinforcement m_T which is equal to:

a) in the case of mechanical tension of the reinforcement

$$m_T = 0.9;$$

b) in the case of electrothermal tension of the reinforcement

$$m_{\tau} = 1 - 0{,}55 \frac{\Delta\sigma_0}{\sigma_0}\left(1 + \frac{1}{\sqrt{n}}\right) \tag{137}$$

and it is taken to be not larger than 0.9.

In formula (137)
σ_0 is the prestressed reinforcement without regard to loss; Δ_{σ_0} is the permissible limit deviation of the prestress σ_0 determined according to Table 26; n is the number of rods, wires, bundles, stressed individually in the construction element (rib, slab, flange,etc).

With the determination of the losses from prestressing, the coefficient m_T is taken to be equal to 1.

Table 26

Length of the reinforcement 1, m	Limit deviation of the preliminary stress $\Delta\sigma_0$, kg/cm2	Length of the reinforcement 1, m	Limit deviation of the preliminary stress $\Delta\sigma_0$, kg/cm^2
5	1000	16	550
6.5	800	19	500
9.5	700	25 and more	450
13	600		

Note: For intermediate values of 1, the limit deviation of the preliminary stress $\Delta\sigma_0$ is determined according to interpolation.

Prestressed road slabs are usually made with tension of the reinforcement on the support. Moreover, the following losses of reinforcement prestressing may emerge:

a) up to compression of the concrete: from the relaxation of the stressed steel, deformation of the anchors, temperature drop and deformation of the form (with tension of the reinforcement on the form);

b) after compression of the concrete: from shrinkage and creep of the concrete and the effect of multiply repeated load.

The total value of all the losses when planning the design of the slab must in all cases be taken not less than 1000 kg/cm^2; the losses from shrinkage of the heavy concrete with tension of the reinforcement on the support are taken to be equal to $\sigma_{\pi 1}$ = 400 kg/cm^2; the losses from creep of the heavy concrete are determined according to the following formula:

$$\sigma_{п2} = \frac{KE_0R}{E_6R_0}\left[\sigma_6 + 3R_0\left(\frac{\sigma_6}{R_0} - 0,5\right)\right], \qquad (138)$$

where σ_b is the compressive stress in the concrete from the force of preliminary compression at the level of the center of gravity of all the longitudinal reinforcements, kg/cm^2; R_0 is the cubic stability of the concrete with its prestressing; E_b is the elasticity modulus of the concrete, appropriate to its planned brand; K = 1 with the use of a reinforcement made of high-strength wire and articles made from it (strands, bundles, cables); K = 0.8-with the use of other types of reinforcements.

In the case where $\sigma_b \leqslant$, the values in the brackets are taken to be equal to zero.

The losses from relaxation of the stresses for a high-strength wire and a strand are determined according to the formula

$$\sigma_{п3} = \left(0,27\frac{\sigma_0}{R_a^н} - 0,1\right)\sigma_0; \qquad (139)$$

for a hog-rolled reinforcing steel of class A-IV

$$\sigma_{n3} = 0,4\left(0,27\frac{\sigma_0}{R_a^n} - 0,1\right)\sigma_0, \quad (140)$$

where σ_0 is the preliminary stress in the reinforcement without regard to loss.

If the loss values $\sigma_{\pi 3}$ calculated according to formulas (139) and (140) turn out to be negative (where $\sigma_0 < 0.37_z{}^H$), then they must be taken equal to zero.

The prestressing losses from creep and from shrinkage of the concrete and relaxation of the steel are basic (in the case of tension of the reinforcement on the support). The other losses are taken as a function of the concrete conditions and the manufacturing technology of the slabs in accordance with recommendations of the CNiP II-V.1-62 "Concrete and Reinforced Concrete Designs. Planning Standards".

When determining the necessary area of the cross section of the stressed reinforcement (total of upper and lower), it is customary by way of orientation to predetermine the value of the total losses:

$$\sigma_n = \sigma_{n1} + \sigma_{n2} + \sigma_{n3}. \tag{141}$$

The area of the cross section of a stressed reinforcement (upper and lower) is determined according to the formula:

$$F_c = \frac{F_б}{\sigma_{aк}} \left[\frac{\{\sigma_н^+\}_н + \{\sigma_в^+\}_н}{2} - \frac{\{\sigma_н^+\}_н - \{\sigma_в^+\}_н}{2} \cdot \frac{W_в - W_н}{W_в + W_н} \right], \tag{142}$$

where F_b is the area of the concrete cross section, cm^2; σ_{ak} is the control stress in the reinforcement, determined according to the formula

$$\sigma_{aк} = m_т \sigma_0 = m_т 0{,}7 R_а^н, \tag{143}$$

where $\{\sigma_H{}^+\}_H$ and $\{\sigma_B{}^+\}_H$ are the values of the necessary concrete compression in the lower and upper grains of the slab, respectively, kg/cm^2; W_H and W_B are the resistance moments of the slab cross section along the lower and upper grain of the slab respectively, cm^3.

The values of the necessary compression of concrete are determined according to the following formulas:

$$\{\sigma_н^+\}_н = \left| \left(\sigma_н^- - [\sigma_р']^-\right) \frac{\sigma_{а.к}}{\sigma_{а.п}} \right|, \tag{144}$$

$$\{\sigma_в^-\}_н = \left| \left(\sigma_в^- - [\sigma_р']^-\right) \frac{\sigma_{а.к}}{\sigma_{а.п}} \right|, \tag{145}$$

here $\sigma_H{}^-$ and $\sigma_B{}^-$ are the maximum normal elongation stresses in the lower and upper grain of the concrete respectively from the effect of automobile load, kg/cm2; $\sigma_{a\pi}$ is the preliminary stress in the stressed reinforcement with regard to all the losses, kg/cm^2, equalto

$$\sigma_{а.п} = \sigma_{а.к} - \sigma_п, \tag{146}$$

where σ_π are the total losses of the prestressed reinforcement, kg/cm^2 determined according to formulas (141) and (138)-(140); $[\sigma_p']$ is the calculated resistance of the concrete at elongation with regard to the repeated effedt of load.

Taking into account that the load causes sign changing stresses in the concrete of the slab, $[\alpha_p']$ is taken to be approximately equal to R_T'(for the given concrete brand) with a characteristic of the cycle $\rho_b \leq 0.1$ ($K\rho_b = 0.75$) i.e.

$$[\sigma_p']^{-} \approx R_T' \approx 0{,}7R_T. \tag{147}$$

The stresses in the concrete σ_H^- and σ_B^- are determined according to formulas (122) and (123).

The resistance moments W_B and W_H are determined according to the formulas:

$$W_B = \frac{I}{y_B}; \tag{148}$$

$$W_H = \frac{I}{y_H}, \tag{149}$$

where I is the moment of inertia of the weakest full slab cross section, cm^4; y_B and y_H are the distances from the neutral axis of the cross section respectively up to the extreme upper and extreme lower grain of the cross section, cm.

After calculating the general area of the stressed reinforcement, we determine the distribution coefficient of the stressed reinforcement between the upper and lower zones of the cross section ψ according to the formula

$$\psi = \frac{W_H}{F_6(e_1+e_2)} + \frac{e_2}{e_1+e_2} - \frac{[\sigma_H^+]_H W_H}{F_c\sigma_{a.K}(e_1+e_2)}. \tag{150}$$

The distance e_1 and e_2 from the neutral axis of the cross section to the centers of gravity of the upper and lower stressed reinforcement respectively isddetermined according to the expressions

$$e_1 = y_B - a_H', \tag{151}$$

$$e_2 = y_H - a_H. \tag{152}$$

In formulas (151) and (152):
α_H' is the distance from the center of gravity of the upper stressed reinforcement to the extreme upper grain of the cross section,=cm;
α_H is the distance from the center of gravity of the lower stressed reinforcement to the extreme lower grain of the cross section, cm.

In the case of single-row disposition of the upper and lower stressed reinforcement (parallel to the neutral axis of the cross section), the distances α_H' and α_H are equal to the thickness of the upper and lower protective layer respectively plus half the calculated diameter of the reinforcement.

Determining the coefficient ψ, we find the area of the upper and lower reinforcement according to the formulas:

$$F'_{H}=\psi F_{c}, \tag{153}$$

$$F_{H}=F_{c}-F'_{H}. \tag{154}$$

According to the obtained values F_H' and F_H, we select the necessary number of rods or wires of the prestressed reinforcement. Then a repeat calculation is carried out with the assumed number of stressed reinforcements in order to specify all the losses of prestressing and to specify the stress cycles in the concrete and in the reinforcement in order to check the durability conditions of the normal cross sections (formulas (119)-(121).

The calculation of the prestressed slabs for durability of the concrete of the inclined cross sections is carried out from condition (66).

Moreover, the greatest main elongation stress in the concrete, kg/cm2 is determined according to the formula:

$$\sigma_{г.р.макс} = -\frac{\sigma_{б.макс}}{2} + \sqrt{\left(\frac{\sigma_{б.макс}}{2}\right)^2 + \tau^2_{мин}}. \qquad (155)$$

In order to determine R'_T, it is necessary to determine the coefficient $K_{\rho b}$, depending on the characteristic of the cycle

$$\rho_б = \frac{\sigma_{г.р.мин}}{\sigma_{г.р.макс}}, \qquad (156)$$

where $\sigma_Г$.p.min is the smallest main elongation stress in the concrete, kg/cm2, equal to

$$\sigma_{г.р.мин} = -\frac{\sigma_{б.мин}}{2} + \sqrt{\left(\frac{\sigma_{б.мин}}{2}\right)^2 + \tau^2_{макс}}. \qquad (157)$$

The stresses $\sigma_{b.max}$ and $\sigma_{b.min}$ from the joint effect of the prestress force and from the load in points of abrupt change in the configuration of the cross section (for example in the level of adjoining of the upper beam flange to the ribs in the ribbed slabs) are determined according to the following formulas:

$$\sigma_{б.макс} = \frac{N_0}{F_б} - \frac{N_0 e_0 y_1}{I} + \frac{M_{макс}}{I} y_1; \qquad (158)$$

$$\sigma_{б.мин} = \frac{N_0}{F_б} - \frac{N_0 e_0 y_1}{I} - \frac{M_{мин}}{I} y_1, \qquad (159)$$

where N_0 is the prestress force with regard to loss, kg; e_0 is the eccentricity of application of the prestress force, cm; y_1 is the distance from the neutral axis to the point of the cross section in which stress is determined, cm.

The force N_0 equals $N_0 = \sigma_{вп}(F_н + F'_н). \qquad (160)$

The eccentricity e_0 equals

$$e_0 = \frac{(F'_н e_1 + F_н e_2)\sigma_{в.п}}{N_0}. \qquad (161)$$

Formulas (158) and (159) are correct only for the point of the cross section lying above its neutral axis. For points lying below the neutral axis of the cross section, the signs in front of the second and third terms of these formulas must be interchangeable.

The maximum shearing stresses τ_{max} are determined according to formula (67), and the mathematical value of the transverse force Q_{max} is determined according to the formulas for calculating the strip (with a width 1 linear m). The dynamic coefficients are taken as equal to their values when determining the transverse force in the slabs without preliminary stressing (see Par. 10), Chapter II). With the effect of the positive bending moment, the transverse force and the tangential stress corresponding to it are minimum and are assumed to be equal to zero in the stability reserve ($\tau_{min} = 0$). With the effect of the negative bending moment, the transverse force and the tangential stresses are maximum and are determined according to formula (67).

The durability of the concrete of the inclined cross sections are considered to be guaranteed if condition (66) is fulfilled. In the contrary case, it is necessary to install clamps (according to the calculation) or to increase the dimensions of the concrete cross section.

12. Method for Calculating Prestressed Reinforced Concrete Slabs for Stability

The calculation of the prestressed slabs for stability (fig. 65) is carried out from the condition

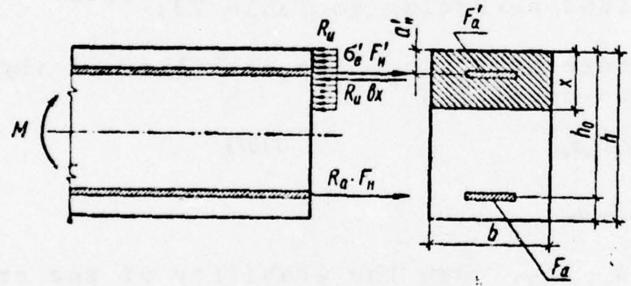


Fig. 65.--Scheme of the disposition of the compressed zone of concrete and the forces in a prestressed slab of rectangular transverse cross section (when calculating for stability).

$$M < R_u bx\left(h_0 - \frac{x}{2}\right) + \sigma_c' F_н' (h_0 - a_н'), \quad (162)$$

moreover, the position of the neutral axis is determined from formula

$$R_a F_н - \sigma_c' F_н' = R_u bx, \quad (163)$$

here σ_s' is the stress in the stressed reinforcement, having a coupling with the concrete and disposed in the zone compressed by the effect of external forces, kg/cm^2.

$$\sigma_c' = 3600 - m_т \sigma_0, \quad (164)$$

where σ_0' is the preliminary stress of the reinforcement with regard to loss, kg/cm^2; m_T is the accuracy coefficient of the prestressed

reinforcement when calculating for stability in the stage of exploitation for a stressed reinforcement situated in the zone compressed from the effect of external forces and having coupling with the concrete, taken as equal to 1.1.

Checking the stability of a slab with rectangular cross section is carried out as a function of the value of the relative height of the compressed zone of the concrete $\alpha = x/h_0$, calculated according to the formula

$$\alpha = \frac{R_a F_н - \sigma_c' F_н'}{R_н b h_0}; \qquad (165)$$

a) in the case where $\alpha_{max} > \alpha \geqslant 2a'_H/h_0$, the stability of the cross section is checked from the condition

$$M \leqslant A_0 R_н b h_0^2 + \sigma_c' F_н' (h_0 - a_н'), \qquad (166)$$

where A_0 is determined according to Table 22 as a function of the value α;

b) in the case where $\alpha \geq \alpha_{max}$, the stability of the cross section is checked from the condition (166), taking $A_0 = A_{0.max}$, where α_{max} and $A_{0.max}$ are determined according to Table 23;

c) in the case where $\alpha < 2a'_H/h_0$, the stability of the cross section is checked from condition

$$M \leqslant R_a F_н z_a, \qquad (167)$$

where

$$z_a = h_0 - a_н'.$$

If moreover $\alpha' < 2a'_H/h_0$, then the stability of the cross section may be checked without reducing the preliminary stress in this reinforcement from the condition

$$M \leqslant (R_a F_н + m_т \sigma_0 F_н') \gamma' h_0 - m_т \sigma_0' F_н' (h_0 - a'_н), \qquad (168)$$

where α' is the relative height of the compressed zone without reducing the preliminary stress in the stressed reinforcement situated in the zone of the cross section compressed fro the external effect.

The value of γ' is determined according to Table 22 as a function of the value

$$\alpha' = \frac{R_a F_н + m_т \sigma_0' F_н'}{R_н b h_0}. \qquad (169)$$

The value of the limit bending moment M_{pr}, which may take up the cross section, is determined according to one of the expressions (166), (167) or (168) as a function of the value of α.

The calculation of the T cross section (from the flange of the beam in the zone, compressed from the external effect), if the neutral axis responding to sufficient stability of the compressed zone of the concrete is situated in the flange of the beam (Fig. 66,a), is carried out as for the rectangular one with a width b_{Π}' (width of the beam flange). In the case where the beam flange of T cross section is situated in the zone elongated from the external effect (for example when calculating ribbed slabs for the effect of the negative bending moment), the calculation of the slab cross section for stability is carried out as for the rectangular cross section with a calculated width equal to the width of rib b.

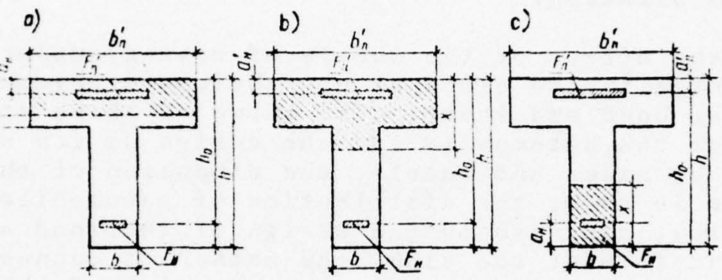


Fig. 66.--Scheme of the disposition of the compressed zone of the concrete in a prestressed slab of T-cross section (when calculating for stability): a-neutral axis passes through the beam flange (compressed zone--part of the beam flange); b-neutral axis passes through the rib (compressed zone--flange of the beam and part of the rib); c-neutral axis passes through the rib (compressed zone--part of the rib).

Chapter III

Materials for Installing Prefabricated Pavements on Highways

§ Working Conditions of the Materials in Prefabricated Pavements

The selection of the materials and the requirements for their physico-mechanical properties are determined by their working conditions in the construction of road surfaces. Monolithic as well as prefabricated road surfaces are subjected to the constant influence of atmospheric factors and the multiple effect of a moving load. The constant load (gravity) is taken into account only when determining the stresses emerging in the slabs in the process of loading-unloading work and installation.

Under the effect of the wheels of moving automobiles, compression stresses emerge in the slabs of prefabricated pavements as well as elongation at bend and shear. The value of these stresses depends on the weight of the automobile and the design of its undercarriage (the number of axles and wheels, the dimension of the tires and the air pressure in them, the distribution of automobile weight between the axles etc), and also on the design of the road surface (the dimension and form of the slab, the method of connection, the nature of the materials, the design and the material of the surface protective layers etc).

The properties of the pavement materials determine what stresses may turn out to be most dangerous (destructive) for them. So, elongation stresses emerging with bend of the slabs under load turn out to be most dangerous for rigid and reinforced concrete pavements. Shear stresses are also destructive in a series of cases for asphalt-concrete as well as for bitumen-mineral slabs.

In order that the slabs of the road surfaces may withstand the effect of a moving load without destruction, they must have certain strength properties. The deformations emerging in the slabs must be elastic. Plastic deformations may be permitted as an exception in struct limits on roads of lower technical categories (in particular, in prefabricated bases of bitumen-mineral slabs). This requirement is guaranteed by the design of the slabs as well as mainly by the properties of the materials used.

The longevity of the road surfaces is determined also by their resistance to the effect of atmospheric factors. Road surfaces are subjected to periodic heating up and cooling off, moisture and drying out, frost and thawing. All this gradually destroys the structural connections of the material and eventually leads to the destruction of the road construction.

The duration of the successful resistance of the road surface to the destructive influence of atmospheric factors is determined primarily by the physico-mechanical properties of the materials used. The constructional disposition of the lavers made of different materials in the road surface is also of great importance. The pavement materials immediately interacting with the atmosphere have the greatest resistance. The base layers are protected on the top by the pavement and the effect of atmospheric factors as well as the effect of moving load is attentuated to a considerable degree. Consequentlv, differentiating requirements must be made on the materials for making the slabs, changing as a function of the intenseness and the nature of the traffic, the designation and the special features of the road surface construction and the climatic conditions in the construction region.

However, the relatively small specific weight of the prefabricated constructions in the general scope of road surface construction and the still insufficient experience in constructing prefabricated pavements and bases are the reasons why up to the present time requirements for all the materials used for manufacturing the slabs have not been worked out clearly and in detail. The more widely used concrete and reinforced concrete slabs are some exceptions. The CNiP has established basic requirements for stability and the frost resistance of the concrete of prefabricated pavement slabs. But these requirements are not different as a function of the working conditions of the slabs. Recommendations are also given in the CNiPe as to the designation of the brands of reinforcing steel. Special requirements for the other materials used in the construction of prefabricated pavements and bases have not been established. Thus in selecting themmaterials used for manufacturing the slabs, we are usually guided by the requirements worked out for materials used in the construction of monolithic pavements. Moreover, it must be taken into account that the quality of the materials for manufacturing the slabs of prefabricated pavements must not be lower than the quality of the materials used for constructing the monolithic pavements.

In a series of instances, prefabricated pavements and bases operate under conditions which are more difficult than similar monolithic designs. They are weakened by the large number of junctions, they are subjected to considerable loads in the period of transportation and installation, especially in the case of repeated dismantling and installation. Thus the selection of the materials for installing the prefabricated road covers, especiallv the pavements, and their quality control must be very careful. The conditions for manufacturing the slabs in special factories and bases of the stationary and semi-stationary type with suitable preparation of the materials makesit possible to obtain a high quality production, which is one of the basic conditions for constructing long-lasting prefabricated road surfaces.

The basic requirements for the materials used for constructing the prefabricated road surfaces are listed below. The methods for testing the materials and the determination of their phvsico-mechanical properties are explained in the textbooks and the educational manuals in the course "Road-Construction Materials" and are not examined at the present time.

14. Requirements on Materials for Manufacturing Concrete and Reinforced Concrete Slabs

Concrete and Concrete Mixtures. The concrete used for manufacturing slabs of prefabricated pavements must have high stability against elongation at bend and to compression, a high degree of density and frost resistance, as well as a high resistance to wear.

CNiP I-D.2-62 establishes that the concrete and reinforced concrete slabs for road pavements must be made of concrete of the brand not lower than 300 in compression strength and not lower than 40 to elongation at bend strength. The concrete must be compact and have a brand of frost resistance not lower than 150 for severe conditions and not lower than 100 for moderate conditions. When testing the concrete specimens for frost resistance, the drop in compression and bending strength after an appropriate number of freezing and thawing cycles must amount to not more than 25%, and the loss in weight not more than 5%. When manufacturing the concrete and reinforced concrete road slabs, it is necessary to be guided by the requirements made on materials for monolithic concrete pavements and bases used in instructions on constructing cement-concrete highway pavements (VSN 139-68, USSR Ministry of Transport).

In accordance with the requirements of this instruction, it is recommended to use concrete of a brand not lower than 400 with a limit of compression strength and not lower than 50 with regard to elongation at bend strength for construction pavement slabs on roads of technical categories I-II. On roads of the IIIrd technical category, it is possible to allow use of concrete of brand 350 with a limit compression strength and 45 with regard to elongation at bend strength. The concrete brand is not taken lower for frost resistance: Frost resistance 100 for regions with an average monthly temperature of the air in the coldest month from 0 to 10°; Frost resistance 150 for regions with an average monthly air temperature of the coldest month from 10 to 20!; Frost resistance 200 for regions with an average monthly air temperature in the coldest month lower than -20°.

To construct monolithic concrete bases, under the improved pavement of the capital type GOST 8424-63 and VSN 139-68 it is recommended to use concrete of a brand with a limit compression strength of 250,200,150,100 and accordingly with a limit elongation at bend strength of 35,30,25,20.

Considerable elongation stresses emerge in the slabs of prefabricated bases (as well as in the slabs of prefabricated pavements) under the effect of gravity when loading into transportation media and when unloading, and also in the process of laying in the road surface. Thus, for slabs of prefabricated bases one should not use concrete with a lower limit of strength to elongation at bend. By way of orientation, it is possible to consider a lower limit of the concrete brand for slabs of prefabricated bases with a limit elongation at bend strength of 30-35. In each particular case it is recommended to determine mathematically the values of the elongation stresses in the slabs with consideration of the special features of the used loading-unloading and installation equipment.

Under actual conditions on the road, the number of annual cycles of freezing and thawing of materials is more for the surface layer and diminishes according to the depth of the road surface. Thus the requirements for frost resistance are less on the concrete for the base slabs (compared with the requirements for the concrete of the pavements). In regions with an average monthly air temperature in the coldest month of the year not lower than -10°, the concrete of the base slabs must have a brand of frost resistance 50. In more mild climatic donditions, the concrete of the base is not standardized.

The concrete brands for sidewalk slabs are recommended to be taken not lower than 300 according to the limit of compression strength and not lower than 40 according to elongation at bend strength. These requirements are taken from the conditions of guaranteeing stability against abrasion and preventing destruction of the slabs with occasional going of the automobile onto the sidewalk. The concrete brands of sidewalk slabs according to frost resistance are designated as a function of the climatic conditions of the construction region just as for the concrete of reinforced highway pavements.

The quality of the cement concrete depends on its composition, the physico-mechanical properties of the used materials and the care in fulfilling the technological requirements in carrying out the work. It is recommanded to plan the makeup of the concrete mathematically-experimentally according to the method proposed by B.G. Skramtaev and Yu.M. Bazhenov (for more details see VSN 139-68). In the process of planning, materials are selected for the concrete and the consumption is determined at which it is most economical to guarantee obtaining the given strength and frost resistance of the concrete, and also the necessary mobility of the concrete mixture (miscibility).

The content of such mixture components such as cement, water and other air-implicating and plasticizing surface-active additions exert an essential influence on the density and on the frost stability of the concrete mixture. The content of the cement, increased in the makeup of the mixture in determined limits, and also the use of cements with a high activity increase the strength properties of the cement rock, which, in turn, facilitates increasing the density and strength of the concrete.

The amount of water, increased per unit of volume of the concrete mixture, does not enter into reaction with the cement (increase of the water-cement ratio), and improves the miscibility of the mixture, but at the same time it decreases density, frost resistance and the stability of the concrete. Fig. 67 shows the dependence of strength on compression of the concrete with crushed stone with settling of the cone 1-3 cm on the water-cement ratio and the activity of the cement [6]. To increase the quality of cement articles and to reduce the cement consumption it is necessary to orient oneself to lower values of the water-cement mixture.

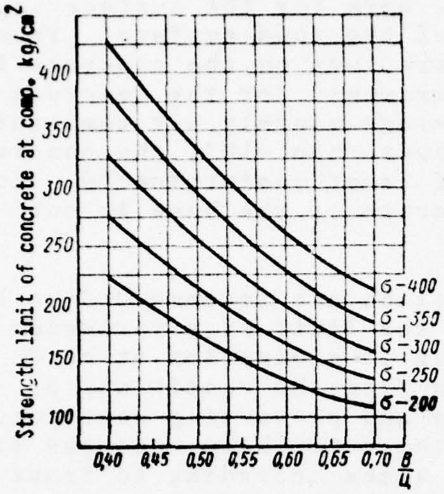


Fig. 67.--Graph of the approximate dependence of the limit of concrete strength at compression on the water-cement ratio W/C and the activity of the cement.

VSN 139-68 established the limit of the water-cement ratio for the upper layers of the double-layered pavement and for and single-layered ones not more than 0.5. At the same time, when preparing the concrete mixture for the lower layer of monolithic double-layered pavements, it is permitted to increase the water-cement ratio to 0.6 and for the bases of improved capital pavements, up to 0.75.

When manufacturing the slabs of prefabricated pavements, and also of the bases, it is necessary to take the water-cement ratio not less than 0.50. The moreso as contemporary equipment of plants in manufacturing concrete and reinforced concrete slabs makes it possible to lay and compact concrete mixtures with a water-cement ratio of 0.5-0.45 and less.

By adaptability we mean the ability of the concrete mixture to assume the form of the article and take on the required density. Since the degree of density depends not only on the composition of the concrete, but on the used means for compacting, adaptability of the concrete is selected as a function of the type and power of the used compacting machines.

In the majority of cases, in plant conditions, compacting of the concrete mixtures is accomplished by vibration with the use of surface vibrators or on vibration tables. This makes it possible to use stringent concrete mixtures for making the concrete and reinforced concrete slabs, having a settling of the cone in limits from 0 to 1 cm and a rigidity determined with the aid of vibration with a technical viscosimeter of 30-80 sec.

Less rigidity is taken when manufacturing slabs of prefabricated bases of small dimensions and reinforced concrete slabs with a large content of reinforcements. The use of rigid mixtures with a low water-cement ratio increases the hardness of the concrete and increases its final strength (see Table 27), and also reduces shrinkage and creep of the concrete.

W/C	Consump. of cement brand 500 kg/m^3	Consump. of water, l/m^3	Needle immersion time, sec	Limit of stability to compression, kg/cm^2: specimens, hardness under normal conditions for one day			specimens evaporated in the course of hours	
				1	7	28	5	12
0.55	295	162	8	79(22)	188(52)	361(100)	236(65)	295(82)
0.40	290	116	45	186(32)	278(48)	586(100)	412(70)	473(81)
0.35	292	102	180	231(36)	306(48)	943(100)	463(72)	535(83)

N

Note: The ratios of stability of samples to their strength at the age of 28 days % are given in the parentheses.

Table 28

Surface-active substance	Amount of addition from the weight of the cement %	Note
Concentrates of sulfite-alcohol residues	0.15-0.25	In calculating for the dry substance of the residue
Soapnaphth	0.08-0.05	In calculating for a commercial solution of soap naphth containing 45-50%.
Acidol-soapnaphth (after saponification or emulsifying)	0.08-0.05	Same
Sodium abietate (abietate resin)	0.01-0.25	In calculating for dry substance

With an increase in the density of the concrete, there is an increase in the frost resistance. Also the presence of fine, closely locked air pores in it increases the frost resistance of the concrete. Hydrophobic, air-implicating substances are introduced to create such pores when the concrete mixture is being mixed. These substances form a non-wetting (hydrophobic) film on the walls of the capillaries which makes it difficult for the entry of water. At the same time, they implicate very fine air bubbles in the concrete. All this, on the one hand, increases the maneuverability of the concrete mixture (its adaptability), and on the other hand it decreases the water penetrability of the concrete, making capillary inflow of the water difficult, which increases its frost resistance.

However, the amount of air-implicating additives need not be extensive in order to reduce the density of the concrete. Thus, their use is limited to small doses (see Table 28 [19]).

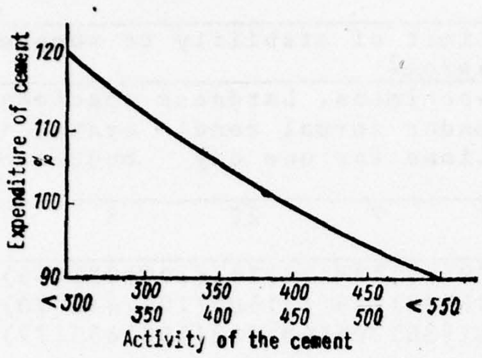


Fig. 68.--Graph the approximate dependence of cement consumption on its activity.

Cements. For the manufacture of slabs of prefabricated concrete and reinforced concrete pavements it is recommended to use plasticizing and hydrophobic Portland cements brand 500 and higher. Suitably surface active substances were introduced into the compositions of these cements in the process of their manufacture. Thanks to this, there is no necessity to introduce them in the manufacture of the concrete mixture. Cements of brand 400 may be used for manufacturing the slabs ofpprefabricated bases. In individual cases, the use of Portland cements and slag Portland cements is permitted in the slabs of bases in case of a suitable technical-economic base with the conducting of preliminary laboratory-experimental tests.

Taking into account the loss of activity of the cements in the storage period (up to 3-5% in a month), they must be used not later than 2-3 months after manufacture. The lower the brand of the cement, the higher (other conditions being equal) their consumption. The dependence of cement consumption on its activity is shown in Fig. 68 [6].

The following requirements are placed on cements, according to their chemical composition, which are used for the manufacture of slabs for concrete pavements [19;32]: they must not contain inert additions; the active additions are permitted only in the form of granulated blast furnace slag, the content of which must be not more than 15%; the content of tricalcium aluminate must be not more than 10%.

Large Fillers. Fractionated crushed stone, obtained by crushing the natural stones of solid rocks must be used as large-scale fillees of concrete for slabs of prefabricated pavements and bases. Crushed stone is better than gravel coupled with cement stone. The use of crushed gravel can be permitted for manufacturing the slabs of prefabricated bases. The use of uncrushed gravel may take place only as an exception, after appropriate experimental checking of the quality of the obtained concrete. To increase the homogeneity of the concrete substance (and to maintain the constant granulometric composition of the large fillers), the crushed rock of the concrete mixtures is dosed individually according to fractions 5-10, 10-20, and 20-40 mm. The largest dimension of the individual pieces must not be greater than 0.25 of the slab thickness. The grain composition of each fraction of crushed rock or mixture of some fractions must satisfy the requirements of Table 29.

In the case of manufacturing reinforced concrete slabs impregnated with a reinforcement, it is desirable to limit the maximum dimension of the crushed rock to 20-25 mm. In the case of a high

Table 29

Dimension of the aperture of the control screens, mm	D_{min}	$0.5(D_{min}+D_{max})$	D_{max}	$1.25D_{max}$
Complete residue on screens in wt.%	95-100	40-70	0-5	0

degree of coarseness, individual, poorly condensed places may remain in such slabs. For densely reinforced and thin slabs, the limit coarseness of the crushed stone is assumed equal to 10; 15 or 20 mm.

The limit strength of the starting rocks, used for manufacturing crushed stone, may be not less than 1200 kg/cm^2 for igneous rocks and 800 kg/cm^2 for sediment rocks.

The weight loss with the experimentation in a shelved drum must be not more than 25% for the crushed rock of igneous stone, 40% for crushed stone of sedimentary rock and 30% for gravel. The frost resistance index of the crushed rock and of the gravel must be not lower than the frost resistance index of the concrete. When determining the frost resistance of crushed stone and gravel with direct freezing, the weight losses of the specimens must be not more than 5%. In the crushed stone and in the gravel there must not be a grain with a plastic (slab) form of more than 15 wt.%. The large filler must be pure. The content of dust, mud and clay particles in it, determined by eluting, must not be more than 1 wt.%.

Just as crushed stone from solid rock, crushed stone from dense, crystalline, blast furnace and Martin slabs may also be used for the concretes of prefabricated pavements and bases. The crushed rock of these slabs has a good cohesion with the cement stone, which increases the strength limit of the concrete to elongation at bend. In regions where metallurgical plants are situated, where the cost of slag crushed stone is relatively low, its use also brings about a considerable economic effect.

Since the blast furnace and open-hearth slabs and theccrushed stone made from them differ by great fluctuations in the physico-mechanical properties, careful laboratory testing is necessary with its use. The strength of the lithium slag intended for fragmentation on crushed stone, usually equals 800-900 kg/cm^2, but in individual cases it may be considerably higher, up to 2000 kg/cm^2 and more.

The weight loss with the experimentation in the shelved drum must amount to not more than 30% for the crushed stone from slag.

To manufacture the slabs of prefabricated pavements, it is necessary to use active slags, the chemical composition of which is characterized by an CaO content of more than 42%, S (with conversion to SO_3) of 4-5% and MnO less than 2%. The content of the crushed stone of slag from blast furnace dust, fuel slags and other foreign admistures must not total more than 3%.

The use of crushed stone from blast furnase slab for making reinforced concrete, pre-stressed slabs in each individual case must be based on special studies, determining the degree of effect of sulfur in the slag on the reinforcement.

Table 30

Sand	Coarseness modulus	Specific surface, cm^2	Full residue on screen 0.63 wt.%	Passage through screen 0.14 wt.%
Coarse	More than 2.5	--	More than 50	Up to 10
Medium	2.5-2.0	--	30-50	Up to 10
Fine	2.0-1.5	100-200	10-30	Up to 10
Very fine	1.5-1.0	200-300	Less than 10	Up to 10

Sand. Natural sands or the same sands obtained by crushing solid rocks, satisying the requirments made on rocks from which large fillers are made are used as a fine filler. The stability of these rocks must not be lower than 400 kg/cm^3. They also use sands obtained by crushing solid metallurgical slags.

The strength of the concrete with the same consumption of cement will be higher with the use of pure large- and medium grained sands. The quality of the concrete drops with the use of sands containing a large quantity of muddy, sandy and also organic admixtures. Thus, the amount of sandy, muddy and clay particles in the sand may be not greater than 3% in natural sand and not more than 5% in crushed sand. Thus, these admixtures must not form individual lumps. The crushed sand isconsidered better since it consists of sharp-cornered, non-rounded particles. The mica in the sand must not be more than 0.5%, gypsum not more than 1%.

The organic admixtures must be less if possible. When processing the sand with a solution of caustic sodium (calorimetric sample in an organic admixture), it must not lend a color to the solution darker than the color of the standard.

The granulometric composition of the sand is characterized by the percent content of grains of different dimensions, and also by the coarseness modulus. The granulometric composition is obtained by obtaining the full and partial residue on screens with apertures 10.0; 5.0; 2.5; 1.25; 0.63; 0.31; 0.14 mm.

The modulus of coarseness is determined as a result of dividing the sum of the full residues on all the screens with apertures from 2.5 mm to 0.14 mm by 100, i.e.

$$M_{\kappa} = \frac{A_{2.5} + A_{1,25} + A_{0,63} + A_{0,31} + A_{0,14}}{100}, \tag{170}$$

where $A_{2.5}$; $A_{1.25}$; $A_{0.63}$; $A_{0.31}$; $A_{0.14}$ expressed in percentages of residue on the screens with apertures in mm, equal to the index with A.

The sands are divided into 4 groups depending on coarseness. Determined values of the modulus of coarseness, the specific surface, full residues on the screen with apertures of 0.63 mm and volumes of siftings through the screen with apertures of 0.14 mm correspond to each of these groups. The values of all these characteristics are shown in Table 30.

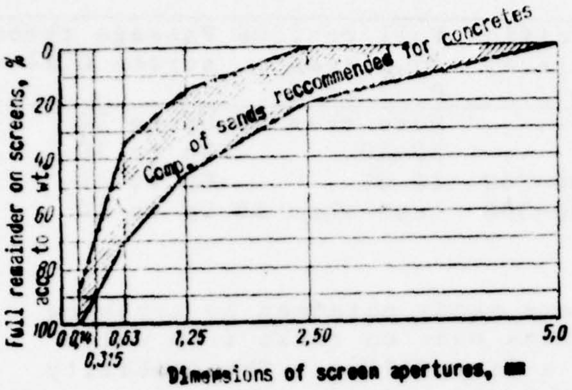


Fig. 69.--Sifting curves of the recommended grain composition of sand for concretes.

The grain composition of the sands recommended for use in concrete mixtures, used for manufacturing slabs, must must be placed in sifting curves shown in Fig. 69 [32].

When checking the suitability of the sands according to the sifting data, their granulometric composition curves are constructed and checked as they are placed in the curves of the recommended compositions. If it goes outside of their limits, then it is necessary to impsove the composition of the used sands by crushing or sifting the grains of some fractions.

The concrete recommendations for improving the composition of the same are given on the basis of laboratory experiments. Usuallv, the composition of the natural sands is improved by additions of artificial sand, obtained by drushing the solid rodks.

The fine-grained and very fine-grained sands are more suitable. When they are used, it is necessary to increase the consumption of cement and to improve the quality of the concrete mixture by introducing additions of a surface-active substance.

Water. To mix the concrete mixture is it necessary to use pure water, not containing any admixtures, which may reduce the quality characteristics of the concrete of the prefabricated pavements. As a rule, such water is water which is suitable for drinking. The hydrogen indicator pH must be not less than 4. The SO_4'' ions must not be more than 2700 mg/l, and the general content of dissolved salts must not exceed 5000 mg/l.

The water must be checked with a chemical analysis. In doubtful cases, the suitability of the water is checked by comparing the stability of the concrete cubes after 28 days which was made with analyzed and clean water. Wasee, industrial water must not be used; neither should water be used from peaty or other contaminated water reservoirs.

Table 31

Color	Pigments: Mineral GOST Name	Pigments: Organic GOST Name	Recommended content of pigments in wt.% of cement
Red	Redoxide MRTU-6-10 567-67	----	5
	Yellww minimum GOST 8135-62	----	8
	Iron oxide ŢUMXP 1911-55	-----	5
Yellow	Iron oxide TUMXP 1927-50	-----	5
	Ocher GOST 8019-56	-----	8
	Natural prussian red GOST 12236-66	-----	8
Green	Chrome oxide GOST 2912-66	Phthalocyanine TUMXP 3289-52	8
	Natural prussian red 12236-66		0.5
Blue	Natural prussian red GOST 12236-66	Phthalocyanine GOST 6220-52	0.5
White	*It is recommended to use white cement*		100

<u>Reinforcing steel</u>. Reinforced concrete slabs are reinforced with rod reinforcements made of hot-rolled steel with a round (smooth) or periodic profile. Cold-drawn wire is also used in prestressed concrete slabs as reinforcements.

Hot-rolled steel of a round profile,are manufactured in classes A-I and A-II, of a periodic profile in Class A-III. The use of reinforcements of periodic profile greatly increases the cohesion of the reinforcement with the concrete, which has special significance when manufacturing slabs with the use of high grade concrete and especially when manufacturing slabs or prestressed reinforced concrete.

The cohesion of the concrete with the reinforcement fluctuates within considerable limits as a function of the concrete brand, its density, the type of reinforcement surface, etc. The cohesion increases with an increase of the concrete density, and also depends on the form of the cross section, the roughness of the surface of the reinforcement. Thus, the resistance of a reinforcement with a square cross section to shear amounts to about 30 kg/cm^3, with a round cross section about 36 kg/cm^2, and with a periodic profile it reaches 60 kg/cm^2 [23].

When manufacturing the slabs, it is expedient to use reinforced welded frameworks or networks. In this case, hot-rolled steel of a periodic profile is usually used as a working reinforcement.

High-strength, hot-rolled steel of a periodic profile or steel, high-strength, cold-drawn wire with a limit elongation strength of 150-160 kg/mm^2 is used for preliminary stressing with the aid of a reinforcement. Frequently, the steel wire is passed through special machines which compress and deform its surface, roughening it, increasing the cohesion with the concrete.

At the present time, experience is accumulating in the succesful use of steel and other brands, besides the ones listed above, as reinforcements. Preferably, especially when reinforcing prestressed constructions, it is customary to use steels with a high strength limit and small relative elongations.

Dyes. To mark the travelled part of the highway, and also to architecturally formulate the sidewalks, it is possible to use colored, cement-concrete slabs. They are given a distinguishing color by introducing suitable dyes into the mixture. GOST 17608-72 recommends use of the dyes (pigments) listed in Table 31.

15. Requirements for the Materials for Manufacturing Asphalt-Concrete, Bitumen-Mineral, Silicate-Concrete and Claydite-Concrete Slabs.

Materials for Asphalt-Concrete Slabs. Preferably, fine-grained, hot, asphalt-concrete mixtures are used for manufacturing asphalt-concrete slabs of small dimensions. The compositions of the mixtures are similar to the compositions used for laying monolithic pavements.

As astringents they use bitumen (or bituminous concrete) with increased viscosity in order to guarantee sufficient rigidity of the slabs in the process of transportation and installation. According to the data of doc. techn. science A.K. Slavutsk, the viscous, petroleum bitumens have a penetration depth of the order of 10-40. More viscous bitumens should be used for work in the southern regions of the USSR, the less viscous ones in the central and northern regions. Crushed solid rock material with a maximum grain size of 8-10 mm is used as fillers. The mineral powder is obtained by grinding the lime. Natural sands should be used with large grains. Natural sand is not added in those cases when rock fines are used as well as screenings obtained with the crushing of rock.

The requirements for the rocks used for drushing are the same as for materials used for constructing monolithic pavements. The stability of the igneous and metamorphic rocks must be not lower than 1000 kg/cm^2, the sedimentary ones, not lower than 800 kg/cm^2.

The requirements for asphalt-concrete slabs of small dimensions are not standardized at the present time. The different road-construction organizations and individual investigators carrying out their own experiments and the data of investigative work establish requirements which are not greatly different from each other. In the majority of cases it is thought that the volumetric weight of the blocks must be not less than 2.3-2.4 g/cm^3, the limit of compression strength at +20° not less than 50 kg/cm^2 and at +50° not less than 20 kg/cm^2. The water absorption should not be more than 0.75%. According to the data of individual authors, it is possible to permit a water absorption of 1.5 and even 2%.

The listed data should be considered average they should be corrected as a function of the climatic region of the construction, the anticipated traffic intensity and its composition.

Materials for Bitumen-Mineral Slabs. Bitumen-mineral slabs are made from hot mixtures of fine-grained, mineral materials (particle size not more than 10-15 mm) with viscous bitumen. Sands, natural gravel-sand mixtures, waste from the mining industry (in particular asbestos waste material) are used as mineral materials.

The requirements for these materials as well as for the specific components of the mixtures for manufacturing the slabs, have not yet been worked out. In the practice of construction, they are oriented by the requirements of the SNiPa, established for rock materials used in monolithic improved pavements. The final conclusion as to their suitability is usually taken according to the experimental data of the finished slabs.

Viscous, petroleum bitumens BND 60/90 and BND 40/60 are used as astringents. When selecting the brand of bitumen, it is necessary to take into account the specific requirements resulting from the working conditions of prefabricated pavement and base slabs. In the laboratory selection of the mixture composition, the viscosity of the bitumen is checked that it provides: a) stability of the finished slab, required according to its working conditions in the road cover; b) stability required according to the conditions of fulfilling the loading, unloading, transport and installation work.

At the same time, the viscosity of the bitumen must not be excessive according to the conditions of limiting the brittleness of the slabs at low temperatures. Thus, the viscosity of the bitumen may be different in different climatic conditions. Even in the same region, it may change depending on the time of the year. When making and laying the slabs in winter time, it is necessary to use bitumen of low viscosity.

To increase the stability and to reduce the porosity of the slabs, it is expedient to introduce mineral powders into the composition of the mixture: ground lime, cement dust, etc.

In average conditions, it is possible to orient oneself to the following composition of the mixture: sand 90 wt.%, mineral powder, 10 wt.%, bitumen BND 60/90 8 wt.% (above 100% of the mineral part of the mixture). Since the physico-mechanical properties of the mixture to a great extent depend on the nature of the starting materials, the composition of the mixture must be specified in detail in the laboratory in each individual case.

At the present time, there is still an insufficient degree of approved technical requirements for the mixtures used for preparing the bitumen-mineral slabs. In the city of Omsk, they are guided by local, temporary, technical conditions, in accordance with which the physico-mechanical properties of the bitumen-mineral mixtures for manufacturing the slabs of the bases of road surfaces must meet the following requirements:

limit of compression strength at +50°, not less than 5 kg/cm^2;

+20°, not less than 20 kg/cm^2;

water absorption according to volume, not more than 15%;

Swelling, according to volume not more than 3%;

coefficient of water resistance $K_v = R_{20}^{water}/R_{20}$, not less than 0.7;

coefficient of heat resistance $K_T = R_{20}/R_{50}$, not more than 5.

These standard require further exact definition. In particular, in the opinion of authors of the present manual, it is necessary to reduce the limit of permissible water saturation to 10%, and the coefficient of heat resistance to ($K_T \leq 3$). The slabs used for prefabricated pavements must be made of dense mixtures. The requirements for them must be the same as for the mixtures used for constructing monolithic pavements.

Materials for Silicate-Concrete Slabs [29]. Artificial monolithic material, obtained as a result of autoclave processing of a specially gathered mixture of lime-sileceous astringent, filler and water is called silicate concrete. The lime-sileceous astringent is obtained by joint thin grinding of the sand and lime. As filler for fine-grained silicate concrete, they use sand, for large grained silicate concrete they use sand and crushed rock with a fraction of 5-10 mm and 10-20 mm.

The brand of silicate concrete used for manufacturing the slabs of prefabricated pavements and highway bases is established in accordance with Table 32.

The volume weight of the large-grained silicate concrete used for making the pavement slabs must be not less than 2200 kg/m^3, and for base slabs not less than 2000 kg/m^3. The volume weight of the finely grained silicate concrete must be respectively not less than 2000 kg/m^3 and 1800 kg/m^3.

Table 32

Concrete name	Concrete brand acc. to limit strength	
	To elongation at bend	To compression
For pavement slabs	60;55;50	500;400;350
For base slabs	45;40;35	300;250;200

Road silicate concrete must meet the same requirements in frost resistance as road cement concrete. The requirements for the fillers (sand and crushed rock) are the same as for the cement concrete fillers. Cases are also known in the practice of civil construction where mutual use has been made of sand and other siliceous magerials. So, in the Ladein Pole and in Liepae, sand is used together with slag, and in the Golodnoi Steppes, local loess [8].

Special requirements are made for sands used for preparing the lime-siliceous astringent. The sands may be of any grain composition, but they must contain not more than 10% admixtures, individually elutrated, and not less than 85wt.% SiO_2, among them not less than 50% free quartz. In the sand there must not be: mica more than 0.5%, water-soluble sulfate more than 0.5%, water soluble alkali more than 2% and carbonates more than 2%.

The lime used for preparing the lime-siliceous astringent must respond to the requirements listed below.

Content of active CaO+MgO,% calculating for dry substance, not less than	70
Content MgO,%, not more than	5
Content of inexhaustible grains, %, not more than	20
Among them burned CaO,%, not more than	3
Content of non-hydrated calcium oxide,% of active CaO+MgO, not less	55
Extinguishing rate, min	
not more than	20
not less than	5

The selection of the concrete composition is guided by the method explained in detail in "Recommendations on the Use and Technology of the Production of Road Silicate Concrete in Conditions of Western Siberia". SoyuzDorNII, 1968.

Materials for Siliceous-Concrete Slabs. The studies of the past years have shown the possibility of using an artificial material claydite as a filler for cement concretes and bitumen-mineral mixtures. Claydite is obtained by roasting the clays of a determined composition. If swelling of the clay takes place with roasting, then we obtain "light" claydite (volume weight 0.2-0.3), used in civil construction. Heavy claydite (ceramdor) is used for road construction, obtained by roasting the clay up to complete agglomeration without swelling.

Claydite is made in the form of grains of round shape with a different coarseness (claydite gravel) or is obtained by crushing calcined pieces (claydite crushed stone).

The investigative studies provide a basis for considering the possible uses of claydite in road construction. But at the same time, the limited scales of experimental work with its use up to now has not provided the basis for working out sufficiently approved technical requirements for claydite or for the fillers of prefabricated pavement concrete.

In the majority of cases, claydite gravel is used with a grain dimension of 5-20 mm and with a volumetric filled weight of 500-900 kg/m^3. The specific weight of the gravel particles equals 900-1500 kg/m^3. Well calcined claydite gravel has a round form with a dense, external crust 1-2 mm thick. The inside part is uniformly porous [18].

The properties of the claydite to a considerable degree are determined by the quality of the used clays and their technological processing. Thus, the characteristics of the physico-mechanical properties of claydite gravel or of claydite crushed stone produced by different factories greatly differ from each other. The properties of the concretes are changed correspondingly with different claydite fillers. However, already at the present time their indicators in a series of cases are close to the indicators of the properties of ordinary cement concrete.

16. Requirements on Materials for Filling the Junctions of Prefabricated Pavements

In the majority of designs of prefabricated highway pavements, provision is made for filling the junctions between the slabs with special materials which must guarantee:

a) water-impermeability of the junctions;
b) protection of the junctions from filling with mud and fine particles of different loose materials.

The requirements for the junction fillers change as a function of the special working features of the junctions in the pavement. A distinction is made between permanent (or almost permanent) width and also a width which changes substantially with a change of the air temperature and of the pavement material.

Junctions of prefabricated prestressed pavements always in a stressed stage (excluding special junctions of widened places) have a constant widty, as do junctions between small slabs which change their dimensions slightly with temperature changes. All other designs of prefabricated pavements have a changed width (in time).

The most widely-used materials for filling junctions of constant width are different kinds of cement and cement-sand solutions. Portland cement brand 500 and higher, pure natural or artificial sand and water are used for their preparation. All these materials

must fulfill the requirements made on materials made for manufacturing concrete and reinforced concrete slabs. The cement solutions usually have compositions 1 (cement) : 0.5 (water); 1;0.75; 1:1. From 0.2 to 1.00 weight units of sand and from 0.4 to 0.8 weight units of water are added to the cement solutions per 1 weight unit of cement.

In each concrete case, the composition of the solution is determined on the basis of laboratory experiments. Freshly prepared solutions must have mobility up to the start of setting which is sufficient so that they fill the narrow junctions between the slabs without delay. After hardening, the solutions must take on a certain stability assumed in the planning of the prefabricated pavement. The highest stability of the solutions in the junctions (close to the stability of the pavement slabs) is required in prefabricated pre-stressed pavements.

In addition to the cement and cement-sand solutions for filling the slabs of prefabricated reinforced concrete and prestressed pavements, high strength solutions may also be used on the basis of epoxide resins (see Chapter V § 26).

Different elastic-plastic materials are used for filling the jucntions of inconstant width (changing with a change in the slab temperature). Their elasticity must be sufficient so that they do not prevent compression of the junction and at the same time they fill the junctions completely with their widening.

The junctions are filled with finished linings and with different cements and pastes.

The finished linigs are narrow ribbons of elastic material. The thickness of the linings must not be less than the width of the junction at the moment of its maximum expansion. The width of the linings is usually equal to or somewhat less than the thickness of the slab.

The stability of the liniggs must be sufficient so that they are not destroyed in the process of carrying out the work (with their installation into the junction) and subsequently they must withstand the effect of traffic, moisture and temperature changes without being damaged.

Different elastic and water-resistant materials are used for linings, for example porous rubber, porolone, insulation. The linings made of porous rubber may have a rectangular as well as a round cross section (Ø up to 60 mm). The linings with a round cross section, compressed in the junction of contiguous slabs, also take on a flat form. The porolone linings are made on the basis of synthetic rubber and rubber waste material with impregnation of different hydrophobic substances. The insulation consists of a mixture of rubber waste products, coumarone resin, bitumen and filler (thinlv ground sand, lime etc). Insulation can be used for the manufacture of the lining, made by the industry in the form of rolls and sheets.

The cement for filling the junctions must respond to the following requirements:

it must adhere well to the walls of the slab;
it must have a sufficient deforming capability at low temperatures (resistance to the formation of cracks) and at the same time it must not be forced upward out of the junction at high temperatures;

it must prevent penetration of water, dirt and other solid particles into the junctions in any weather;

it must have durability, for example it must equal the durability of the slabs.

The cement must be used in the finished form as manufactured by industry as well as in the form made directly at the place of construction. They are mixtures of various astringents and elastic materials, flowing when heated up and solidifying at ordinary temperature.

The bitumen-rubber cements made at the site of the construction consist of mixtures of bitumen, rubber flakes, asbestos flakes and mineral powder. The ratio of the components changes as a function of the climatic conditions at the construction site and the design of the junction. The narrower the junctions and the lower the air temperature, the less the viscosity of the cement must be. The following composition of rubber-bitumen cement is recommended for the IInd climate zone by VSN 169-69:

Bitumen brand BND60/90	60%
Mineral powder	20%
Asbestos powder	10%
Rubber flakes	10%

The softening temperature of the cement of such a composition must be not less than 60°. When it is necessary to obtain a cement with a different softening temperature, the suitable mixture is selected in the laboratory, changing the percent content of its components:

For pouring narrow junctions with a width of less than 5 mm, they use cement in a cold state, prepared on the basis of rapidly decomposition or slowly decomposing bitumen emulsion with an addition of latex SKS-65 in an amount of 15 wt.%. The composition of the rapidly decomposing bitumen emulsion is as follows:

Bitumen BND 40/60	50%
Water	48.14%
Exidol-soap naphtha	1.50%
Liquid glass	0.20%
Caustic soda	0.16%

Composition of the slowly-decomposing bitumen emulsion:

Bitumen BND40/60	50%
Water	48.5%
SSB (dry substance)	1.5%

This cement may also be used for pouring wider joints in cold weather at air temperatures close to 0°, when the hot cement rapidly solidifies and fills the junctions poorly.

Domestic industry produced a series of cements requiring heating up when used. The best known are insulating cement, rubber-bitumen, Thiocol hermetic. Insulating and rubber-bitumen cements are mixtures, the basis of which are viscous bitumen and rubber fragments. Asbestos fragments, coumarone resin and other additive are added to it in different proportions.

Table 33

Cement	Materials entering into the composition of the cement, wt.%						
	Rubber dust	Bitumen BND 40/60	Alloy Vpl	Coumarone resin	Colophony	As-bes-tos	Fine sand
Insol N-1	19	60	--	4	2	15	--
Insol N-2	20	75	--	5	--	--	--
TSN-2	--	24	56	--	--	6	14

According to the data of the SoyuzDorNII [39], the paste "Izol" produced by industry is best.

Composition of some cements, listed in Table 33 [23]. [See table].

The alloy V-1 is a material of natural bitumen from a Sizransk deposit.

In severe climatic conditions, it is necessary to orient oneself to the use of Thiocol sealer. Thiocol sealer is a mixture of special pastes and additives, regulating their vulcanization processes. Studies of the past years show a good quality of the Thiocol sealers. The composition of the Thiocol sealer of brand U-30 MES-10:

Sealing paste	100 wt.%
Vulcanizing paste	15%
Diphenyl guanidine (DFG)	not more than 1 wt.%
Acetone	12-15 wt.%

The mixture of the sealers is prepared in cold condition before pouring into the joints. After sealing, they are vulcanized (converted into a material similar to rubber).

17. Materials for Prefabricated-Sectional Temporary Roads

Prefabricated-sectional pavements of temporary roads must withstand repeated assembly and disassembly without damage and have the least possible weight per unit of area (to decrease the expenditure in their transport). In accordance with these requirements, it is necessary to select the materials for manufacturing the slabs.

At the present time, it is customary to use the same materials for slabs of temporary roads with anrelatively extended period of exploitation (several months or years) as for slabs of main road surfaces: cement and silicate concretes, lithium slags. Slabs made of reinforced concrete are extensively used on temporary forest and construction roads. The requirements for these materials for the manufacture of slabs from them for pavements of temporary roads remain the same as with the construction of roads of the permanent type.

The greatest shortcoming of prefabricated pavements of these materials is their great weight.

Slabs of bitumen mineral mixtures and asphalt-concrete are usually not used for the pavements of temporary roads. The insufficient durability of these slabs leads to their considerable damage during disassembling and transport.

Reducing the weight of concrete and reinforced concrete slabs is possible by replacing the cement concretes with plastic concrete. Concretes in which different synthetic resins are used for astringents are called plastic concretes. With their use (for example with the use of epoxide resins) it is possible to greatly increase the strength of the concrete and correspondingly to reduce the thickness of the pavement slabs. So, plastic concrete was obtained under laboratory conditions with compression strength limits up to 600-1200 kg/cm^2 and strength to elongation at bend of up to 100 kg/cm^2.

At the present time, plastic concretes have limited use because of the high cost of synthetic resins and the comparatively small volume of their production. However, the use of plastic concretes will expand with the further development of the chemical industry.

So-called "inventory" designs of prefabricated-sectional pavements are used on temporary roads with short periods of exploitation, made of wood or of metal. The guards of wood pavements are made of forest materials of the type which are resistant to decomposition. Usually, the selection of the type to a considerable degree is determined by their presence where the work is being carried out. If possible, preference is given to coniferous types (pine, spruce, larch).

Steel and different aluminum alloys [3] produced by industry are used to make metal pavements. So St 3 is used for simple designs and rigid slab frameworks. For pavements made of corrugated metal they use high-quality carbon steels, better susceptible to stamping. Lighter constructions can be obtained from aluminum-magnesium alloys AMg-6 and AMg-61 and also from alloys of brand V-92T, systems Al-Zn-Mg (Cu). These alloys are for example 3 times lighter than steel St 3, but at the same time their strength characteristics are lower (se Table 34). Nevertheless, the use of these alloys makes it possible to greatly reduce the weight of prefabricated-sectional pavements.

Other types of steels and alloys (not shown in Table 34) may be used to make metal sectional-prefabricated pavements. With their selection, in addition to the strength characteristics, it is necessary also to take into account the possibility of using welding for connecting the individual elements. Some types of aluminum alloys cannot be welded. The connection of the elements used for such alloys usually is accomplished by rivets which greatly complicated carrying out of the work and increases the volume of labor.

Table 34

Type of metal	Volume weight		Yield stress	Strength limit		Medium specific strength	Relative elongation %	Modulus of elasticity		Modulus of shear $кг/см^2$
	$кг/м^3$	Per cents %		$кг/см^2$	Percents %			$кг/см^2$	Percents %	
Ст. 3	7850	100	2400	3800—4700	100	540	21	$2,1\times10^6$	100	$8,1\times10^5$
Ст. 20	7850	100	2400	4000	100	510	25	$2,1\times10^6$	100	$8,1\times10^5$
АМг-6	2660	34	1600	3200	76	1200	15	$0,71\times10^6$	33,8	$2,7\times10^5$
АМг-61	2660	34	2100	3800—4100	93	1480	12	$0,71\times10^6$	33,8	$2,7\times10^5$
В-92Т	2720	34,6	2200—3200	3900—4600	100	1560	9—15	$0,71\times10^6$	33,8	$2,7\times10^5$

CHAPTER IV

THE TECHNOLOGY OF MANUFACTURING PREFABRICATED HIGHWAY SURFACES

SECTION 18. GENERAL INFORMATION

The production of prefabricated structures is composed of a line of operations: receiving, storing and transporting the materials, preparation of the mixes, manufacturing of the reinforcement elements, and their placement into forms, molding the products and their sheet treatment, storing the finished products and distribution to consumers.

Reinforced concrete slabs for prefabricated surfaces are manufactured in special plants for reinforced concrete products and in special yards.

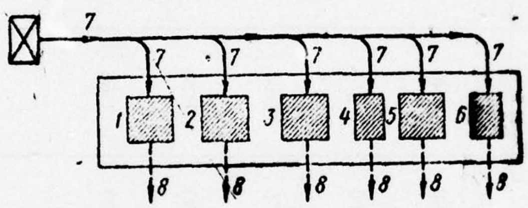


Fig. 70 Bed scheme for the production of prefabricated reinforced concrete structures and parts:
1-6: moveable forms on the bed; 7: combinding the reinforcement and the concrete mix in the forms; 8: transfer of the finished structures and parts to storage.

The manufacture of slabs of silicon concrete is carried out in special factories, equipped for the milling of sand and lime, and with autoclaves. For the manufacture of asphalt-concrete and bituminous slabs, in the majority of instances asphalt-concrete plants are used, in which special shops or open yards are constructed. At the present time reinforced concrete structures are primarily produced in specialized factories, providing a higher productivity of labor, better quality and lower product cost.

In factories the production line conveyor and bed technologies are used in the molding of reinforced concrete products. In yards the bed technology is used in the majority of instances.

By the bed method of production, (fig. 70) the molding and hardening operations are performed in stationary locations-in the beds. The products in this process are molded, hardened and

subsequently cured in one place, so the technological equipment for performing the separate operations is not moved from one form to the next. The immobility of the products at the time of production limits the importance of mechanization and automation of the productive processes. Accordingly, the significant part of the operations is carried out by hand.

The production line method of manufacturing reinforced concrete products, (fig. 71) the forms are moved from one station to the next with production intervals depending on the duration of the operations at each station.

Line of motion of the forms

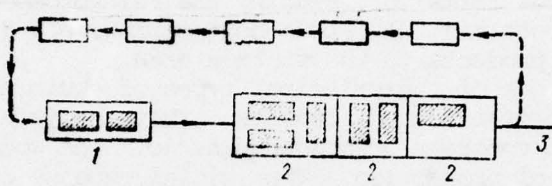
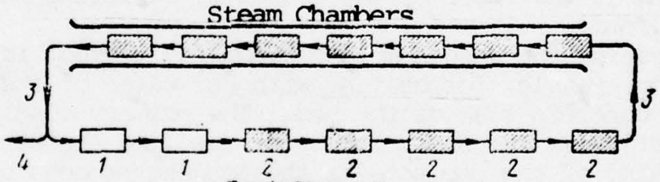


Fig. 71. Production line scheme of manufacturing prefabricated reinforced concrete structures and parts.
1 - Form assembly; 2 - Steam chambers; 3 - Striking; and inspection and dispatching of the finished products to storage.

The steam-heat curing of the products is done in a pit type steam chamber, divided into sections according to the dimensions of the products.

Steam Chambers



Cart-Wagons

Fig. 72. Conveyor line scheme of producing prefabricated reinforced concrete structures and parts.
1 - Wagons passing through preparation stations. 2 - Wagons passing through preliminary molding stations. 3 - Roller conveyor. 4 - Striking of the finished products and dispatching them to storage.

This method of manufacturing requires less expense for the organization of production and permits the easy retooling for the output of new types of products by means of a high level of mechanization.

The conveyor line method is characterized by the driven rhythm of motion moving the form-wagons from one station to the next. Conveyor production (fig. 72) is composed of several technological lines with succesive work stations, at which separate operations are performed. The disadvantage of conveyor production is the complexity of tooling and difficulty

of readjustment for the output of new types of products. Though for massive manufacturing of one type of product, the conveyor line is much more productive.

The bed method of reinforced concrete and concrete products production takes place in yards as well as in factories. This method is expoditiously used in the manufacture of large size structures in factories of small capacities with a wide range of products.

With a small volume of production, and a short period for the exploitation of equipment (3-5 years), it is most expeditious to manufacture prefabricated structures by the bed method in yards.

In the productive process for manufacturing prefabricated reinforced concrete structures by the bed method, the following sequence is performed: a). Preparation of the forms; b). Placing the reinforcement; c). Pouring and compacting the concrete mix; d). Steam-heat curing; e). Striking; f). Transfer of the finished products to the storage area.

The forms are one of the principal types of equipment in the manufacturing process for prefabricated products. They are made of wood, metal, concrete, reinforced concrete or molded plastic. The wooden forms permit only a small volume of production. The initial expense of wooden forms is far and away less than that of metal or reinforced concrete for the same products, but the turnover of the latter is significantly less.

In economizing on metals with this method, concrete or reinforced concrete beds and matrices with side casing are produced from preformed metal-wooden or reinforced concrete elements.

Pouring the concrete mix into the form on the bed is accomplished with a belt concrete placer. The concrete mix is carried from the concrete mixing shop to the belt concrete placer by a bridge crane with a transfer hopper.

The steam-heat curing of the products is properly produced either by various means in the floor of the bed or by admitting steam under the covering of each form.

For heating the wooden molded products, the bed is equipped with special devices. For example, for heating with hot water or steam, steel pipes are laid in the concrete slab of the bed. The primary condition for the bed method of production is the abbreviation of the time the structure stays in the bed. Hardening of the products is the longest process of the productive cycle, because of that, abbreviation of that time is the most important factor in the acceleration of output and the reduction of product cost.

In the yards the primary method of manufacturing structures on a bed is the heatless method, using quick setting cement. In heating, the products are molded and subject to heat curing directly on the lines (on the ground or in pit or semi-pit type chambers). In fig. 73

the pit type chambers are shown as used in yards.

For the reinforcement of the products manufactured on short beds, hot rolled deformed reinforcement tendons are used. The stress of the reinforcement is produced by jacks and with the help of electroheating.

On the long beds several single type products may be placed simultaneously. This leads to a significant reduction of cost with relation to the placement, stressing and anchoring of the reinforcement, because these operations are done simultaneously for all products placed on a single long bed.

Of the number of long beds, the packet and extended variety have received the greatest currency. Into the composition of the packet bed enter:

Cross section

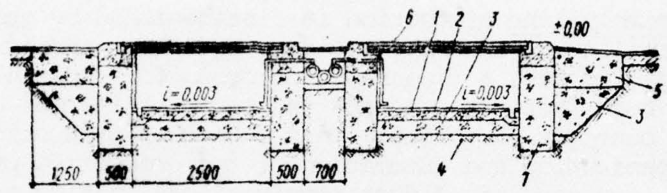


Fig. 73. Pit type steam chambers:
1 - cement stress shackle; 2 - reinforced concrete slab; 3 - leveling layer of slag; 4 - packed soil; 5 - concrete; 6 - chamber cover; 7 - chamber walls

Placement for the wire packets and one or several molding floors, designated for stressing and molding the products. In the placement simultaneously guide and pull one or two wires, which then will be grouped into packets and fasten them to the clamp devices. The packets of reinforcement are stressed by an SM-513 type stressing machine with a 60 T. capacity. With the help of a standard stressing machine (60 T.) in one packet up to 24-28 wires with a 5 M.M. diameter may be placed.

In the molding area there is a steam trench having at its ends, supports for taking the force of the stressed reinforcement.

The extended beds do not have special placements for the wire packets. The extension of the wires, and the fastening of their ends in anchor plates is done directly on the molding floor. The ends have several lines, between which are laid rails for moving the concrete placer and transfer trolley. At the end of each line is a concrete support.

At the head part of the bed along the supports are laid two railways, along one moves the trolley with the concrete placer, along the other, the stressing machine.

At the tail end is a traversing route and transfer trolley for the transfer of the concrete placer from one line to the other. The same is provided for the pulling wench.

Extended beds do not have steam chambers, and are designed for the use of steam jackets or for steaming under canvas.

The merit of the bed method of production is in the simplicity of the equipment and it's universality. The disadvantage of this method is the low volume of production per unit of space and the comparatively low level of mechanization.

The line manufacture of products envisions the completion of all operations at special stations with the rhythmical movement of the form and product which may be organized by a production line or conveyor line method.

The assembly line production is distinguished by great flexibility and maneuverability of the manufacturing equipment and is used in factories of medium capacity with a wide range of products. Low initial cost of equipment in such factories reduces the scale of initial expense in comparison with conveyor factories. This method of production allows a high level of mechanization and automation of the productive processes. The transfer to a new type of product requires less in time and resources than with the conveyor method of organizing production.

The process of manufacturing prefabricated structures and parts by the production line method of production may be performed in the following technological sequence: a). Preparation of the forms; b). Placing the reinforcement; c). Transfer and pouring of the concrete mix; d). Compaction of the concrete mix; e). Transfer of the molded products to the steam chambers; f). Steam-heat curing of the product; g). Extraction of the form with the product from the steam chamber; h). Transfer of the finished product to storage.

By the production line method of manufacturing prefabricated reinforced concrete products, the forms are carried from one station to the next by a bridge crane. The concrete is fed from the concrete mixing shop to the concrete placer with the aid of a feed belt or self-propelled trolley on a trestle. The concrete placer distributes the mix into the forms mounted on a vibrating table. The molded products in carts are fed to the pit type chambers by the bridge crane for steam-heat curing. From the chambers the products are transported by self-propelled trolley to the storage area for finished products.

The conveyor method of production of prefabricated concrete and reinforced concrete structures is organized in factories with great capacity with a mass output of a single type stable production.

The particular feature of the conveyor method of production is that the process of manufacturing products is distributed on a line of technological

operations, each of which is succesively completed at one of the conveyor stations. By this method of molding products, the forms move from one station to the next in strict sequence and at a determined rate of speed.

After passing all stations, the products in the wagon are fed into tunnel type steam chambers, from which the finished products go to storage, and the form-wagons back to the conveyor.

The most important factor in the organization of this method of production is the mechanization of transfer between operations, connecting the separate links of the technological process into one single chain. In this way, the means of transportation serve not only for the moving of the products, intermediate products and other materials, from one work place to the next, but also for the maintenance of the invariable steps of the production line.

The process of manufacturing prefabricated reinforced concrete and concrete products by the conveyor method may be performed in the following technological sequence: a). Placement of the side casings; b). Cleaning and lubrication of the cars and side casings; c). Winding the wire for placement of the reinforcement tendons in the supports; d). Placement and fastening the mounting reinforcement and imbedded elements; e). Pouring the concrete mix into the form-wagon; f). Compaction of the concrete mix; g). Control inspection of the product and transfer to the steam chamber; h). Steam-heat curing of the products in the steam chambers; i). Extraction from the steam chamber and striking; j). Transfer of the finished product to storage and return of the form-wagon to the conveyor.

With the manufacture of unreinforced products, the general sequence of the technological process is in a viably preserved, but operations on the intermediate products or the form reinforcements are excluded.

The manufacturing of slabs of prefabricated surfaces of other materials (silico-concrete, bituminous mix, lithium slag) is performed by technologies taking into account the strengths and technological properties of each material. Though generally, for all these materials, the basic stages of the technological process remain:

a). Preparation of the forms (cleaning, lubricating, and placement);

b). Placement and fastening of the reinforcement.

c). Preparation, placement and compaction (with the exception of lithium slag) of the materials.

d). Setting of the materials into the forms (by a special regime, and in special cases with additional curing).

e). Striking the products and transportation to storage.

The details of carrying out each operation are determined by the specific peculiarities of the material and the equipment used.

SECTION 19. MANUFACTURE OF REINFORCED SLABS IN FACTORIES

At the present time, the USSR has created a powerful well equipped prefabricated reinforced concrete industry, providing a wide range of output.

The production of reinforced slabs for highway construction may be organized in general construction factories as in factories organized especially for providing for the needs of road construction.

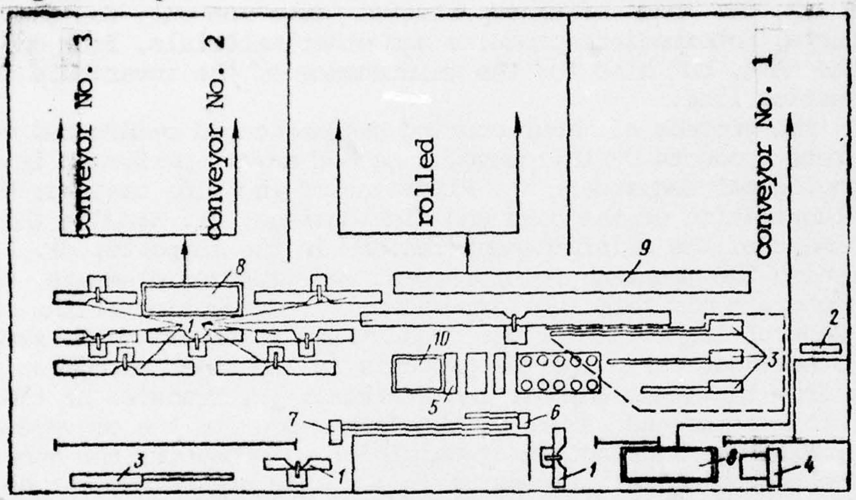


Fig. 74. Diagram of the equipment network of the reinforcement shop.
1 - MTP-75 machines. 2 - Machines for disbursing the mesh to the slab rolling mill. 3 - S-338 machines. 4 - MTMS-7x35 machine. 5 - ATMS-14x75 automatic welding machine. 6 - S-370 driven welding shears. 7 - Model S-150 of the same. 8 - OS-1 and K-1 meshes. 9 - Flat frames. 10 - Mounting meshes.

In the majority of instances, currently operating reinforced concrete products factories work by the conveyor line or production line technological schemes. In separate cases, the bed technology is also used.

The main body of reinforced concrete product factories have these production shops: Reinforcement, concrete mixing, molding, electrical, mechanical repairs, carpentry, boiler, compressor, and electrical substation. The reinforcement shops are equipped with a complex of automated and semi-automated equipment and necessary devices for the welding of mesh and frames. A diagram of the equipment network of the reinforcement shop is shown in fig. 74.

Preparation of the reinforcement includes these operations: straightening, cutting and bending the reinforcement tendons. For cutting the reinforcement of small

diameters use S-150 and S-338 machines and Nosenko automatic construction machine.

The S-150 machine is intended for cutting reinforcement steel with a diameter up to 40M.M. It may cut tendons (with a diameter 22-44 M.M.) or bundles (of diameters 5-22 M.M.).

The S-338 and Nosenko automatic construction machine serve for straightening reinforcement steel with diameters of 4 to 14 M.M. For the cutting and straightening of reinforcement steel with a diameter of 16 M.M. a D-5 straightening-cutting machine is used.

Bending reinforcement tendons for fitting into the forms is done on a special bending machine. For bending heavy reinforcements with a diameter of up to 40 M.M., use a driven S-146 machine, and for bending reinforcement of small diameter, a NZ-4, on which reinforcements with a diameter of 4 to 20 M.M. may be bent. Reinforcing steel, straightened and cut into tendons must be of the necessary dimensions to be fed to the welding machines.

For continuous electrical spot welding of the reinforcement mesh, high production universal automatic ATNS-14x75 machine of the Leningrad factory "Elektrik" is installed. This machine simultaneously welds 24 spots, cuts mesh to the necessary dimensions, feeds the intermediate product into the machine and guides the mesh under guillotine shears. The maximum width of the mesh is 2700 M.M. (of wire with of a diameter of 3 to 10 M.M.). The pitch of the cross tendons may be equal to 100, 150, 200, 250, and 300 M.M. The length is arbitrary. The productivity of the ATMS-14x75 is 1200-1500 M.M.S.Q. per change.

The work of the automated line begins after the placement of the wire coil, passing the ends through the proper apparatus and placing them under the electrodes. The necessary movements, and clean welding operations occur with the help of neumatic cylinders and electrical guidance systems. In the event that longitudinal cutting of the mesh becomes necessary for the production of the necessary length, after the automatic welding, longitudinal and latitudinal shears are included.

The labor consumption of manufacturing mesh is reduced by 30 to 50% by the described automated line.

The sequence of operations for advance treatment and preparation of the reinforcement steel is shown in the diagram porvided below.

For the removal of oil lubricants and the cleaning of high tension wire, use a special set up (fig. 75). The coil of high tension wire is rewound on a drum. With the help of clamps, it is rough cleaned. After this, the drum with the high tension wire is immersed in a solution of caustic alkali, set into the support with a conical socket, finally rewinding the wire through 3 to 5 clamps. Into 1 cubic meter of water, pour 30 to 40 liters of potassium-lithium electrolyte containing a 40% solution of caustic potash and a 1.6% solution of lithium hydroxide.

SEQUENCE OF OPERATION FOR THE TREATMENT AND PREPARATION OF REINFORCEMENT STEEL

Storage of Reinforcement Steel

Band reinforcement steel
↓
Cutting of the metal to dimensions
↓
Bending the rod steel | Manufacture of the tendons
↓
Bending the bar steel

Steel in coils
↓
Cutting and straightening of the metal
↓
Cutting the metal to dimensions
↓
Manufacture of the reinforcement mesh

Rewinding is done in the solution at a temperature of 80 to 90 degrees C. If the high tension wire has an insignificant oil film rewinding need be done once, that is:

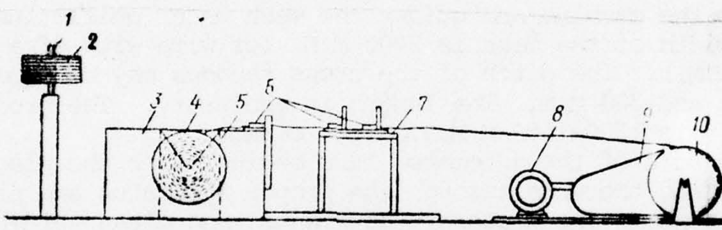


Fig. 75. SET UP FOR THE DEGREASING OF HIGH TENSION WIRE: 1 - rotor; 2 - reel with high tension wire; 3 - bath for caustic alkali solution; 4 - drum for rewinding; 5 - support; 6 - clamps for stripping wire; 7 - stand for the clamps; 8 - electric motor; 9 - reduction gear; 10 - drum with cleaned wire.

The wire goes directly from the rotor to the bath, from which it goes through the clamps and is rewound on the drum. The average productivity of this set up per change is 0.65T. of wire.

In the manufacture of prestressed reinforced concrete slabs for highways various methods of stressing the reinforcement may be used. No methods of stressing reinforcement have received such wide currency in the manufacture of prestressed reinforced concrete slabs, as the electro-thermal stressing of reinforcement tendons and bundles, continuous stressing with the help of reinforcement-coiling machines and the electro-mechanical stressing of reinforcement wire.

The essence of the electro-thermal method of reinforcement stressing is that the reinforcement parts are heated with an electro-thermal current to the needed length, they are affixed in that condition to a rigid support or in the end of solidified concrete. The supports and end prevent the contraction of the reinforcement parts when cooled, because of this stress occurs in them. The electro-thermal method of stressing reinforcement is used

advantageously with the manufacture of prestressed reinforced concrete structures, reinforced tendons of high alloy or with deformed high carbon steel.

The importance of the electro-thermal method of prestressing steel is significantly broadened in the production of structures. In contrast to the forced stressing of reinforcement tendons, in which every tendon is separately pulled, the electro-thermal method uses the pulling of all tendons of the reinforcement tendons, in which every tendon is separately pulled, the electro-thermal method uses the pulling of all tendons of the reinforcement evenly and simultaneously, creating an even swage of the concrete in the pulled elements. For reinforcement with tendons by the method of electro-heating, use 30KhG2S type steel, with tinsel strength of 9000 KG/C.M.^{2} and a yield strength of 6000 KG/C.M.^{2}. Preparation of the tendons with welding clamps takes place in the reinforcement shop in a bed by a strictly *formulated pattern*. The tendons are manufactured with such calculation so that the distance between the supports is greater than the length of the tendon stretched to its greatest length by heat. The end anchors or clamps on the reinforcement tendons are intended for the fastening of the tendons to the form support or to beds of hardened concrete until the strength of prestressing is sufficiently transferred to it. The type of end anchor on the reinforcement tendon depends mainly on the type of support and the scale of production.

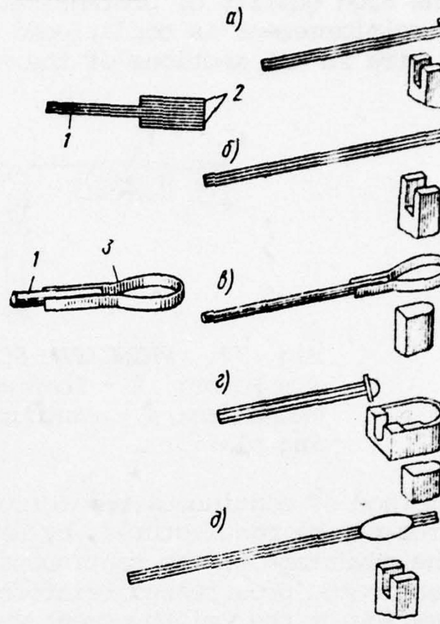


Fig. 76. END ANCHORS FOR PRESTRESSED REINFORCEMENT.

a). Tendon with welded shorts; b). Tendon with button head; c). Tendon with loop grip; d). Tendon with button head and permanent loop; e). Flattened tendon. 1 - tendon; 2 - short; 3 - loop.

At the current time the following 3 types of end anchors have received wide currency (fig. 76).

1. The anchor, made on the end of a tendon in a hot state. Tendons with this type of anchor are used with forked supports and in cases of massive production of products.

2. The anchor, made by welding on the end part of the tendon a short of round steel or deformed steel. It is used with forked supports and in cases of small scale production.

3. The anchor, made by welding to the end of the reinforcement tendon a loop of band steel, used with pronged supports.

The method of continuous reinforcement consists of the winding of the wire on the car prong with the help of a coiling machine. At this point, the whole reinforcement represents a continuous fiber, being equally pulled with the appropriate force.

The high quality of prefabricated structures manufactured using continuous reinforcement is conditioned upon the equal stressing of the high tension wire in all sections of the structure.

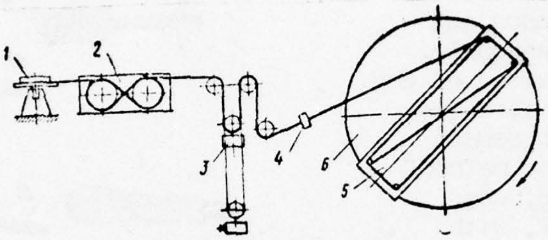


Fig. 77. **PRINCIPAL SCHEME FOR DN-5 TURNTABLE**
1 - Rotor; 2 - Feed mechanism; 3 - Stressing mechanism; 4 - Pantograph; 5 - Cart; 6 - Rotating platform.

By the method of continuous reinforcement, as shown in the model, a variety of structures may be manufactured, by using a bileveled and biaxis winding.

The advantage to the continuous method of reinforcement in the production of prefabricated prestressed reinforced concrete structures is the importance of automation of the reinforcement work and significant economy of metal.

For continuous reinforcement use high tension (tinsel strength 15,000-18,000 KG/C.M.^{2}) waved wire. With the continuous method of reinforcement, with high tension wire, the operations of cutting and straightening the reinforcement, construction of anchors and the use of clamping and stressing devices are dropped.

For the continuous winding of the reinforcement wire, use the following types of reinforcement-winding machine.

1. A turntable. With the rotation of the car, fastened on to the table, the wire from the reel passes through the pulling blocks and is would on prongs rising from the car (fig. 77).

2. The ENEMS reinforcement-tie bar structure, on which the car is fixed and revolving above it, a trunk, winding the wire on special structures of the car (fig. 78).

3. The semi-automatic SM-607 machine (fig. 79) is a bridge with a roto-translatioanl motion above the fixed car, winding of the wire takes place with a frame moving like a shuttle across the bridge.

4. The portable universal DN-7 winding machine, moving self-propelled along the bed on a frame on which is installed stressing equipment and a trunk of the lateral motion mechanism reeling out wire (fig. 80).

The necessity of improving the technology of continuous reinforcement led to the creation of a combined eltro-mechanical method of stressing, the use of which eliminates breaks and significantly raises the productivity of winding machines.

The method is thusly consisted: The wire is pulled by a weight or a special breaking sleeve to 35-50% of the target stress. The remaining stress in the wire is created on account of this, so in the process of passing it from 1 block to the car it is heated by an electrical current to the temperature of 250-300 degrees C. and at this temperature wound. Cooled, the wire is additionally stressed to the target limit.

The key step for the orginization of slab production is the method of molding the products. The compacting of the concrete mix is the primary operation, determining the entire process of molding the products. The compaction may be done with the aid of vibration, vibrostamping,

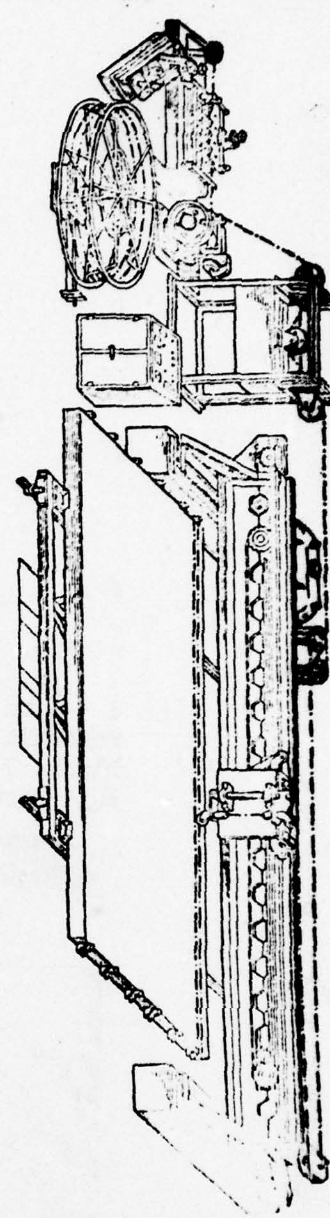


Fig. 78. ANM-ENEMS REINFORCEMENT-WINDING MACHINE

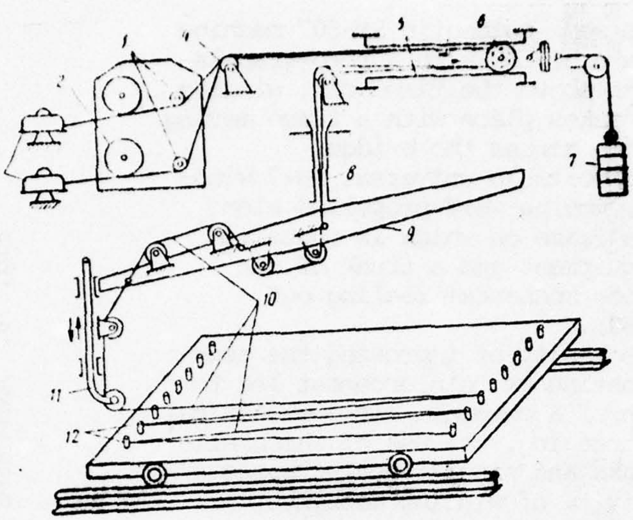


Fig. 79. SCHEME FOR THE SM-607 REINFORCEMENT-WINDING MACHINE

1 - Wire coil; 2 - Electro-magnetic breaking sleeves; 3 - Feeding mechanisim blocks; 4 - Intermediate block; 5 - Guides; 6 - Sliding block; 7 - Weight; 8 - Central guiding conduit; 9 - Traverser; 10 - Wire; 11 - Discharging block; 12 - Cart trunks.

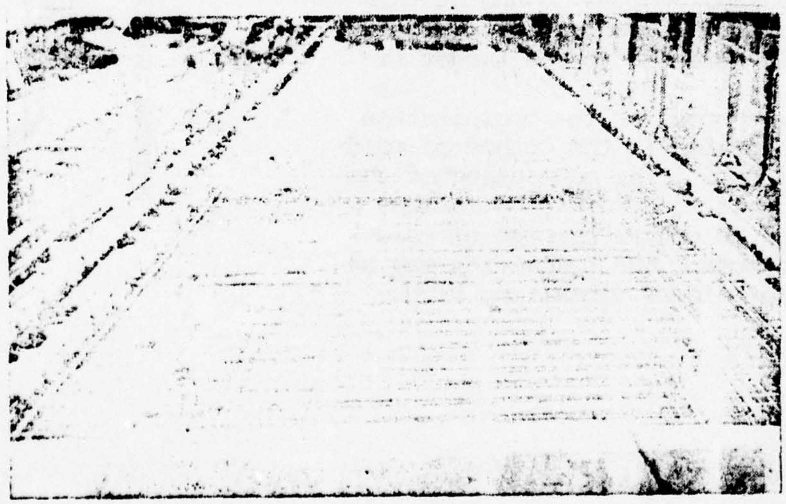


Fig. 80. DN-7 UNIVERSAL WINDING MACHINE

vibro-vacuum processing, and spinning methods of compressing rolling.

The high quality of the compaction reaches a defined condition depending on the vibration mobility of the mix, the form and size of the course aggregate. Molding with concrete mix compacted by vibration may be used with any method of production. The fundamental unit for the compaction of the concrete mix by the production line and conveyor methods of production is the vibrator table, consisting of top works (oscillating) frames and lower works immobile and fastened to the base and absorbers placed between them. In molding products from mobile concrete mix in some instances use vibration in combination with vacuum processing. The removal of air and extra water after vibration with the help of a vacuum-brush, vacuum form or vacuum core is used to raise the strength of the vacuum-processed concrete in a span of 2 to 3 days by 40 to 60% and in the span of 28 days, by 20 to 25% higher than the strength of regular vibrated concrete.

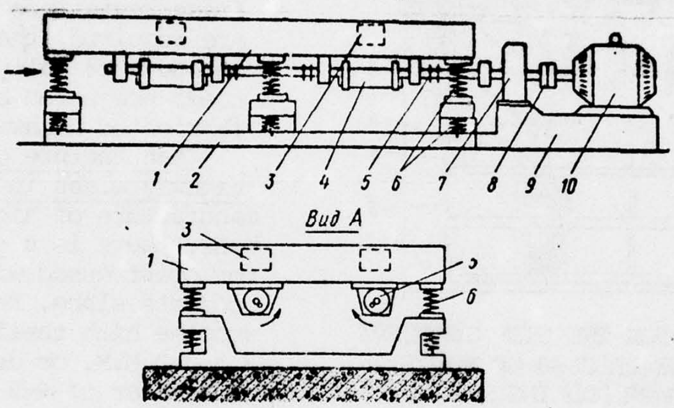


Fig. 81. SCHEME OF VIBRATING TABLE WITH CONTROLLED OSCILLATIONS.

1 - Upper frame of vibrating table; 2 - Lower frame; 3 - Electromagnet for fastening form to vibrating table; 4 - Disbalances; 5.- Shaft; 6 - Springs; 7 - Reducer-synchronizer; 8 - Sleeve; 9 - Base; 10 - Motor.

With the conveyor method of production, activization of the hardening of the products is accomplished in a tunnel type continuous motion chamber, in which the necessary temperature and relative humidity are maintained. The length of the continuous motion chamber is divided into 3 zones: heating, thermostat, and cooling. In each special zone exists separate constant temperature and humidity conditions. The molded products move along in the chamber on a cart from one zone to the next. Duration of the stay of the products in each zone is determined by the length of that zone and the rhythm of movement of the products through the chamber. The continuous motion chamber, by contrast with

the period motion chamber produces a higher quality of product, thanks to the greater ease of acheiving uniformity in heating and cooling.

A highly effective method of manufacturing highway slabs is power vibro rolling.

Power vibro rolling is the molding of concrete products with the multi-stage compaction of the mix in combination with intensive pressure on the concrete from above by means of a network of succesive rollers (fig. 82). The parameters of the vibration and pressure are altered from the first roller to the next in accordance with changes in the elastic-plastic properties of the concrete mix, determined by the measure of it's compaction.

This method of power vibro rolling has been effectively associated with the manufacture of products from which, the sides high strength, significant density of structure, heightened frost resistance and durability are required, that is, this method more fully answers the needs presented by slabs for prefabricated highway surfaces.

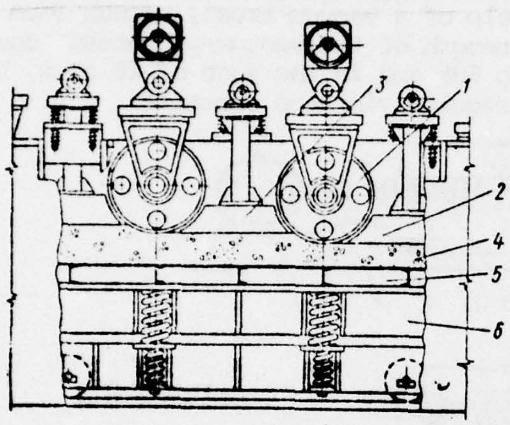


Fig. 82. SCHEME FOR THE STEP SWAGGING OF THE MIX IN THE PROCESS OF MOLDING PRODUCTS IN A POWER ROLLING STAND.
1 - Vibrating roller; 2 - inter-roller vibrating plate; 3 - Cavity for the heat-transfer of the inter-roller vibrating plate; 4 - The products; 5 - Cart with cavity for heat transfer; 6 - Overhead vibro press form.

Manufacture of prestressed highway slabs in beds. With the manufacture of highway slabs in beds, there is a greater economy for prestressed wire reinforced concrete slabs, reinforced with smoothe high tension wire of 2.5-3.0 M.M. or deformed wire with a diameter of 4-5 M.M., having a rated resistance of 9,5000 - 11,500 K./C.M.^{2}.

The bed designated for the manufacture of slabs is equipped with a DN-7 type self-propelled reinforcement winding machine, used to carry out the dual axis reinforcing with prestressed reinforcement, the concrete placer, a complex of vibro stamp forms and hoisting equipment.

The dimensions of the bed (the gross length) are determined by calculation on the basis of the productivity of the reinforcement-winding machine, with an acounting of the productivity of product steam-heat curing limiting the duration of the entire technological cycle.

The vibro stamp machine is made of two parts -

the side parimeter casing and the top load producing stamp die. The side casing must have slots for passing the reinforcement down the casing into the bed.

It is recommended that the stressing of the wound wire be done by the electro-thermal method of wire stressing (by contrast to force stressing). To the end of utilizing the existing capacity of the reinforcement-winding machine and raising its productivity, simultaneous winding of a doubled number of wires is recommended. Heating of the wires must not exceed 300 degrees C.

The bed equipment with prongs arranged along the long sides, allow the fastening of anchor prongs at any point on the line. Besides this, there must be end supports which may be fastened to any point in the width of the bed. They have the ability to move across the bed. Use fixtures for the spot placing and fasten a fastening of the vibrating deck.

The ends of the stressed wire are fastened with the help of special clamps, preventing slippage.

Transfer of the stressing force from the support prong structures to the hardened concrete takes place smoothly, slowly and simultaneously from all supports and prongs. With the unimportance of freeing supports from the stressing force swagging the concrete by the succesive step method is permissable. In this case, the transfer of force from the support to the concrete follows a division of not less than 4 steps. The slab manufactured by the bed method using the DN-7 machine proceeds to the next form.

By the working drawing determined the needed quantity of reinforcement, imbedded parts and other materials, varifying their quantity and quality. It is necessary to assemble and carefully lubricate the component support prongs before beginning the work. The prongs are put in sockets in the bed in accordance with the winding diagram of the reinforcement and are fastened at the necessary height above the bed. The plane of the bed and the vibro stamp machine, contiguous with the concrete, are carefully cleaned and lubricated.

Check the reliability of the electrical insulation of all rollers, sections of the reinforcement-winding machine and bed which touch on the heating section and also check the working conditions of the electrical wiring and the current carrying contacts.

For heating the wires in the continuous winding process, use an electro welding transformer type TS-300 and TS-500 with secondary voltage not greater than 60v.

Before the winding, again check the correctness of the prong placements put in an enclosure around the reinforcement-winding machine, fasten the end of the wire and regulate the position of the spindle

in order to create the necessary thickness of the protective layer on the lower surface of the product.

By stressing the reinforcement after winding every horizontal line it is necessary to apply safety clamps to preserve the winding in case of a break in the wire. The winding of the reinforcement is followed at once by the production of the entire quantity of slabs, placed in separate sections of the bed, restricted by the end supports.

The stressing of the reinforcement during the process of winding is monitored systematically by readings of a volt meter and an amp meter. Monitoring of the stressing with the help of measuring devices at least once every 24 hours is necessary for production.

Strap loops are installed after the winding of the reinforcement stressed by the electro thermal method and after the cooling of the wire to room temperature.

Pouring the concrete mix is carried out by a vibro concrete placer, final compaction and evening of the upper surface of the slab is done by a special vibro stamper with a small load. With the compaction by the vibro stamper, the concrete mix is doled out by weight (from calculations of the volume of the product, it is possible to get the gross weight of the concrete mix in a compacted state) or by volume in a compacted state in the measured hoppers of the concrete placer.

Transfer of the force of prestressing in the reinforcement from the support to the concrete occurs following the attainment by the concrete of a strength not less than 250 K.G./C.M^2 as measured by testing the block.

The prongs freed from the force are properly rotated by srench to 1.5 - 2 revolutions of the head of the streching bolt and the ends of the supports moved on a horizontal wedge with the aid of a powerful screw jack.

The wires protruding from the porduct are cut only after the removal of stress from all prongs and support ends. The cutting of the wires may be done by any method (rotating discs, electo-welding apparatus, gas torch cutters etc.) and in any sequence.

<u>Manufacture of prestressed reinforced concrete blocks by the production line method</u>. By this method of manufacturing slabs, continuous coiling and stressing of reinforcement in moveable or portable forms is used. For this, a special automatic coiling machine is used, providing the important reinforcement by a given scheme.

The ANM winding machines have received wide use working by the crane scheme. These are much more universal machines and so, may be used in any scheme of winding stressed reinforcement. They work both by automatic and hand control.

In fig. 84 the scheme of the sequence of winding high tension wire in two lines (by height) and in two directions is shown, in fig. 84 a cart with stressed wire reinforcement is shown.

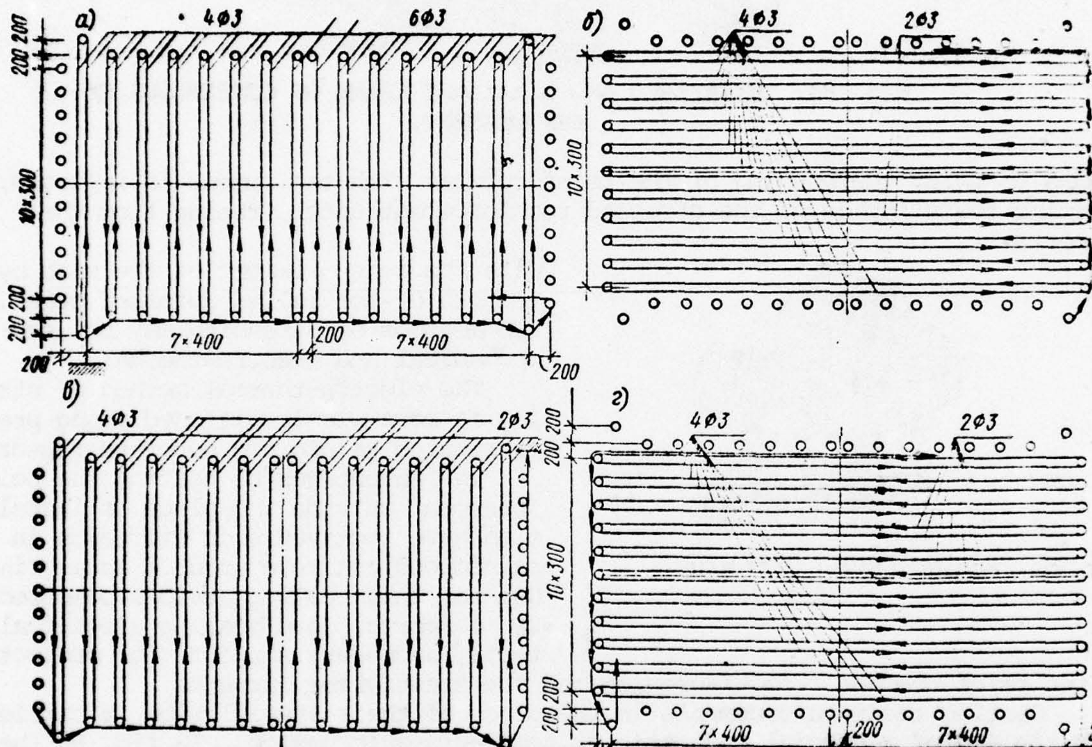


Fig. 83. SCHEME FOR WINDING HIGH TENSION WIRE.
a - Winding the wire in the lower line in a latitudinal direction; b - the same, but in a longitudinal direction; c - the upper line in a latitudinal direction; d - the same in a longitudinal direction.

The high tension wire at the time of winding on the coiling machine goes through the process of waving. A special waving apparatus (fig. 85) makes dents on the exterior surface of the wire of a defined depth and pitch.

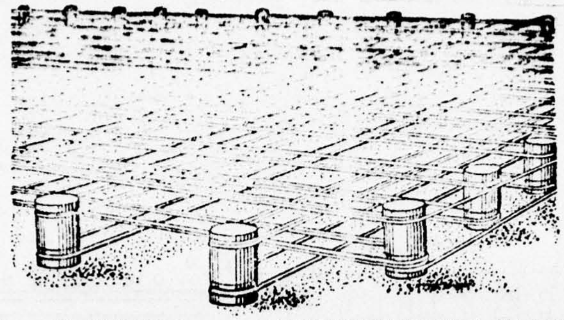


Fig. 84. BILAYERED AND BIAXILARY FRAME OF CONTINUOUS REINFORCEMENT.

Thanks to this, the bonding of the reinforcement with the cement is improved, averting the slippage of the stressed reinforcement after freeing from the supports.

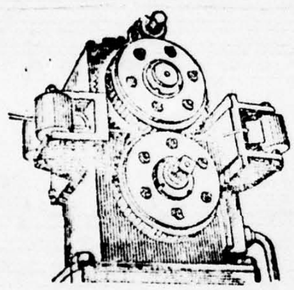


Fig. 85. WAVING DEVICE FOR WIRE

With the reingorcement of the slab by tendons of hot rolled deformed steel, two methods of stressing may be used: mechanical and electro-thermal.

The electro-thermal method of stressing is more widely diffused among prefabricated reinforced concrete factories.

The advantages of heating the reinforcement outside the place of installation have received wide diffusion in the reinforced concrete product enterprises. Use for this heating devices composed of two supports, load bearing electrical contacts, secondary supports for protection of the reinforcement from slackening and the transformer currents.

Heating the reinforcements in the place of their installation is carried out with the aid of a special automatic or semi-automatic device. In fig. 86 the semiautomatic device is shown, which was deviced by the Ural branch of the AC and A Academy of Construction and Architecture of the USSR and the Chelyabmetallurgstroi trust. In it several tendons or bundles may be simultaneously heated along their entire length. The manual operations of connecting the contacts, insulating the bundles or tendons from the form and placing them between the supports is entirely eliminated.

The device is composed of a support frame 1, placed on this is a moveable carriage, 2, clamps, 3, for the reinforcement, to which are fastened current carrying cables. The carriage moves with the aid of a neumatic cylinder. The force developed in the nuematic cylinder and occuring in a single tendon is not less that 120-150 K.G.

A form or cart is fed to the device and is put with the front end close to the support frame. Reinforcement tendons (bundles) manufactured in the needed length-shorter than the form-are placec in the slots in the supports. From the front side of the form to the tendons the carriage clamps are set. Air is fed into the nuematic cylinder and the carriage begins to move away from the form pulling the tendons somewhat and elevating them above the form.

After the introduction of the current, the tendons are heated add expanded in length. When the tendons reach their designated size,

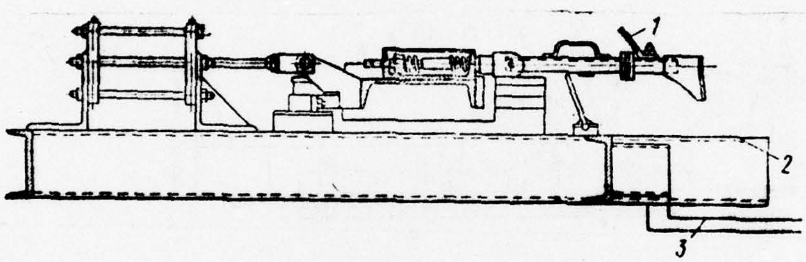


Fig. 86. SEMI-AUTOMATIC DEVICE FOR HEATING THE REINFORCEMENT AND PLACING IT IN THE SUPPORT OF THE FORM.
1 - to the transformer; 2 - level of the upper plane of the cart; 3 - level of the lower plane of the cart.

The carriage, activating the end switch disconnecting the electrical chain and switches the electro-neumatic valve which controls the cylinder. The result of which is that the carriage alternates it's motion. By this the clamps under the influence of their own weight fall down and the tendons are lowered into the slots in the front of the form support.

The device is supplied by two or three welding transformers. The scheme used and the type of transformer chosen depends on the number, length and diameter of the reinforcement.

In the product line thechnology of molding, the slabs are produced on carts where the products remain from the moment of pouring the concrete mix until the removal of the finished product. After the stressing of the reinforcement and the placement of all imbedded metals and the lifting loops, the cart wagon is fed to the molding place and lowered on to a vibrating table. The vibrating table is composed of a welded box frame operating on four springs. On the lower surface of the frame is a powerful electro-magnet which draws the cart wagon.

After the placement of the cart wagons on the vibrating table lower the side casings and firmly affix the imbeded elements. Then the self-propelled concrete placed passing above the form pouts the first layer of concrete mix which is leveled and compacted by the vibroplacer, mounted in the hopper of the concrete placer. On the second pass the concrete placer lays the second layer of concrete mix and partially finishes the surface of the products. Smoothing of the mix is done with the placer.

For the final finishing of the slab surface use a ceiling machine mounted on the self-propelled concrete placer (fig. 87), which operates on a frame on which are placed quide rollers. Along the rollers move two ceiling apparatus - 1. A welded channel bar frame with a vibrating racks, making a reciprocal motion, and 2. A smoothing shaft with a diameter of 300 m.m., placed before the vibrating racks and revolving with a speed of 4,000 rev./min.

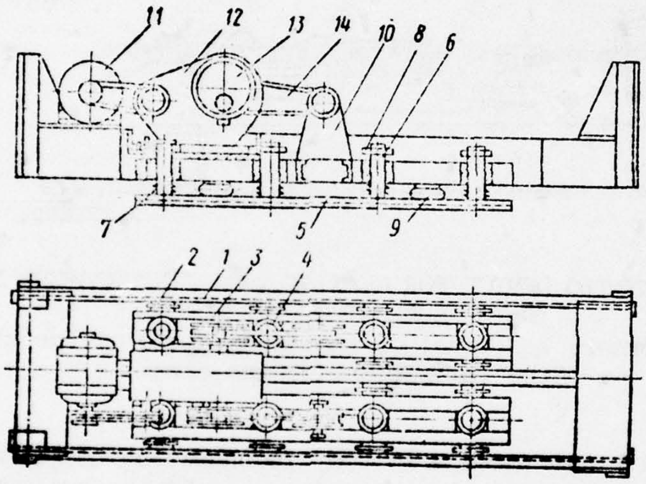


FIG. 87. Ceiling machine placed at slab surface molding station: 1 - machine frame; 2 - guiding rollers; 3 - frame of ceiling device; 4 - guiding hub; 5 - vibrating rack platform; 6 - cylinders; 7 - springs; 8 - locking ring; 9 - vibrators; 10 - cantilever; 11 - electric motor; 12 - reduction gear; 13 - cams; 14 - connecting rods

After the final evening of the slab lower the side casing, strike it and feed the formed product with the aid of a traversing trolley which can hoist or lower the product and guide it to the hardening chamber.

A more widely used means of producing the accelerated hardening of the concrete and attainment of the designed strength in a period of one to two days in factory conditions is the heat-steam curing operations with steaming in chambers of continual periodic motion (fig. 88).

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The steaming is done with saturated steam of a relative humidity of 90-100%. The chambers of continual motion are tunnels, through which during the time of heat treatment the carts with the products are continually moved.

The chambers are divided by length into three zones with various temperature regimes. Structures being produced in form carts are gradually moved through the chamber, passing successively from one zone to the next.

In the beginning the products are fed into the preheating zone with a air temperature of 20-40 degrees C., then to the heat treatment zone (here the temperature is around 75 degrees) and finally, to the zone of cooling and humidification of the products, where the temperature is gradually lowered to 30-40 degrees C. The zones in the heating chambers are divided from each other by an ear by ear type curtains. These curtains are also installed at the ends of the chambers.

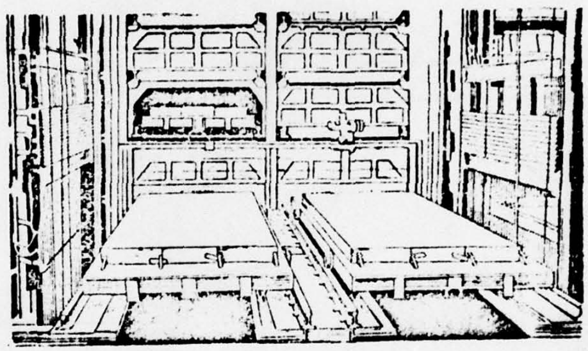

Fig. 88. Feeding freshly formed surface slabs on cart wagons to teared heat treatment chamber.

The average period of steaming the reinforced concrete structures is divided into three periods: 1. The time of raising the temperature in the chamber and initial heating of the concrete, 2. the isothermic preheating (maintaining the temperature at one given level) 3. cooling of the products. Given the final strength of the concrete and temperature of preheating, the period of heating-steaming may be established in accordance with the schedules.

The speed of raising the temperature during the heating of the reinforced concrete structures and parts without forms consists of not greater than 10 degrees an hour in the beginning of initial heating and not greater than 20 degrees an hour at the end; for structures and parts steamed in the form, the speed of raising the temperature will be 15 and 25 degrees an hour respectively. The duration of the period of raising the temperature is from two to three hours.

The period of isothermic preheating lasts from 10 to 15 hours with the optimal temperature between the limits of 70 to 80 degrees. In these conditions

after steaming the strength of the concrete reaches 70% of the designated strength in a 28 day period.

Lowering the temperature (the period of cooling) takes about 1.5 hours. Thus, the average duration of the cycle of steaming reinforced concrete structures in the chambers lasts from 14 to 20 hours, and taking into account the time of loading and unloading - from 17 to 24 hours. The temperature, the duration of heating) is established experimentally accounting for all local conditions of the technological process.

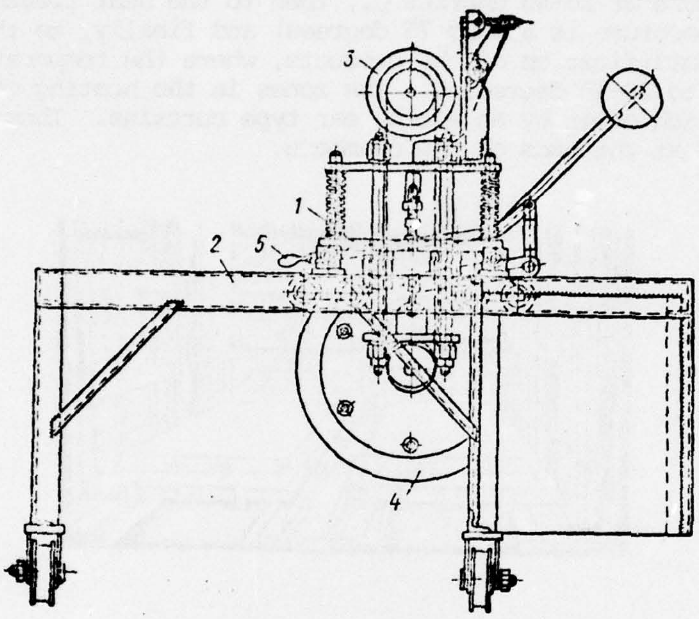

Fig. 89. Electrical disc saw; 1 - carriage; 2 - frame; 3 - electric motor; 4 - disc; 5 - lever.

On removal from the chamber the slab is fed to the station, where the loops of the stressed reinforcement, which transferred the stress to the concrete are cut. Until not long ago, cutting the end of the stressed reinforcement was done in factories with the help of electrical welders. Now this labor consuming operation is done mechanically. In factories with line production there have been installed special mobile placements with discs which cut off the ends of the reinforcement tendons (fig. 89).

The cutting disc is revolved by an electric motor. On the surface of the cart, moving on a rail, is fastened an electric motor with the capacity of 10 kilowatts. By means of a V-belt the electric motor rotates the metal disc at a circular

speed of 120 m/sec. The frame moves along a railway along the conveyor above the product. By applying pressure on the lever the disc is lowered to the tendon and cuts it. With the cross motion of the cart along the guides all protruding ends of the reinforcement tendons are successively cut.

The expenditure of time in cutting 12 bundles of high tension reinforcement steel of two sides or 12 tendons of 30 AhG 72 S steel with the help of an installed disc saw is 1.5 minutes against 7-9 minutes with an electrical welder.

After the transfer of the stress to the concrete and removal of the products from the cart wagons they are placed by crane onto a self-propelled trolley and moved to the storage area for finished products, the carts are returned to the station of cleaning and placement of the reinforcement. In the storage area of the finished products the slabs are placed in piles with wooden spacers between them with a distance of 5 meters between the piles. The productivity of the line is 250 m^2 of such plates in a shift.

Production of prestressed highway slabs on a vertical conveyor. The vertical bi-leveled conveyors of reinforced concrete product factories consists of two lines: Work and the return line. In the work line a continuous trolley train is placed, consisting of separate cart wagons; for the return line use the free space under the bed frames.

On the work line of the conveyor the following zones are provided: Zone for the placement of the reinforcement mesh and placement of the prestressed reinforcement; zone for concrete casting and gauging of the upper surface of the products; zone for curing the product; zone for striking, cleaning and lubricating the carts.

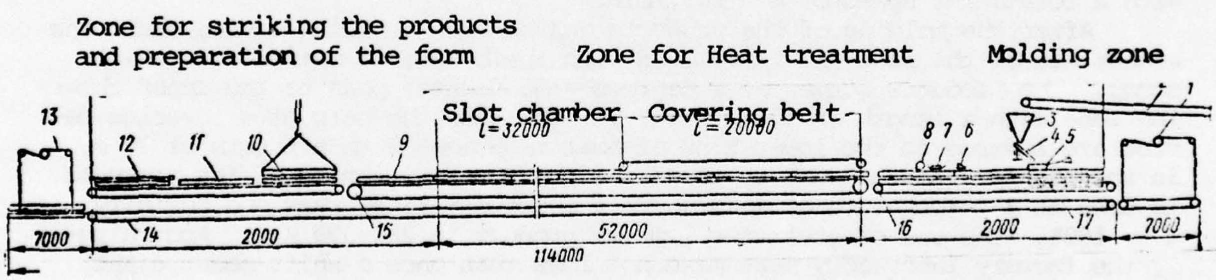

FIG. 90. SCHEME OF VERTICAL CONVEYOR:
1 - hoist; 2 - concrete transport feeder; 3 - piling hopper; 4 - rotary flow apparatus; 5 - vibrating element; 6 - plane; 7 - smoothing ski; 8 - gauging shaft; 9 - station for striking the slab; 10 - station for cutting the reinforcement and edging; 11 - station for cleaning and lubrication form; 12 - station for placing the reinforcement; 13 - lowering device; 14 - drive belt for striking zone; 15 - drive belt for heat treatment zone; 16 - drive belt for molding zone; 17 - vibrator implacement.

In fig. 90 is shown the scheme of the vertical conveyor. The working operations for the manufacture of highway slabs are conducted in the following technological sequence.

After striking the products, the form carts are cleaned and lubricated. Clean of adhering solution and concrete the wagon form, the end and side casings, the plate, the imbeded element fixtures, the grooves, the lifting loop fixture and the supports on which the reinforcement is stretched. The forms are cleaned with mechanical brooms and scrapers, equipped with hoses for compressed air. In cleaning the forms do not permit use of hammers, sledges or crow bars. Lubrication of the surface of the form is carried out with the aid of a rod sprayer evenly applying a layer no greater than 1 m.m.

Into the composition of lubricant goes: a) EKS emulsion with an acid number of 8-10-20 %; b) saturated lime solution(1 g. Ca $(OH)_2$ in 1 L. of water disolve at T degrees equals 60 degrees) - 80%.

Store the finished lubricant at a temperature constantly betwen 55-60 degrees. Use 0.25L. of lubricant per 1 m^2 of surface of the wagon.

In working the tendon for prestressing heat on an electrical contact device to a temperature not greater than 300 degrees C. Before their placement install the lower mesh and fix it at the height with the aid of special plastic mass filling elements. Then fasten the heated tendons to the form supports and install the imbedded elements and hoisting loops. After the final welding of the properly placed side casings, the reinforcement and imbeded elements of the form cart are fed to the molding station.

Produced in the concrete blending section the mix is fed to the molding station by a feed belt. Flowing through a turning trough, the mix evenly fills the continually moving and vibrating form. The speed of the form movement is 15 m/min. The excess concrete mix is removed from the surface of the slab with the aid of a transverse finishing ski placed along the course of the form motion at an angle. The final finishing and grading of the top surface of the slab is done with a quick moving shaft of a diameter of 240 m.m. with a rotational speed of 470 rev./min.

After the molding of the products and before the quick moving shaft the excess mix at the last ski is removed with the help of a matrix or special scoop. The products pormed at T degrees = 30 degrees pass to the upper cheering zone with a length of 30 m. (fig. 91) and with the help of a lowering device are lowered to the lower zone of heat treatment with a length of 70 m, in accordance with the work cycle of the conveyor. Steaming of the procucts is done at a temperature of seam where T degrees = 85 degrees and humidity W = 100%. The use of steam for 1 m^3 of product is 260-300 k.g. Accordingly the factory laboratory must make not less than once a shift measurement of the temperature in the chamber and make the necessary correction in the regime of steaming.

From the steam chamber the finished product is fed to the striking station, where the end and side casings of the form are removed

and the transfer of the prestressing to the concrete slab is carried out. Transfer of the stress to the concrete is properly carried out in cutting the reinforcement tendons near the form support.

Fig. 91. General view of molded products cheering station.

After exterior inspection and typing of the slab it is sent to the storage area for finished products (fig. 92).

Thorough surface inspection of the slab produced on a vertical conveyor, has shown that the accepted technology of their production fully provides for a higher quality of surface, keeping the necessary tolerance and sufficient strength of the product. Besides this the specialized separate zones, the high degree of mechanization

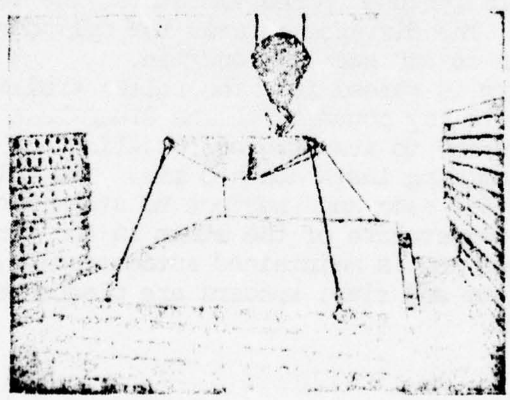

Fig. 92.

used significanlty elevate the productivity of molding and other equipment, intended for the production of separate types of products, and reduces the consumption of labor.

The manufacture of highway slab on a forced vibrating slabbing mill. The forced vibrating slabbing mill is used in a technological flow, the compositional elements of which are: molding zone (pouring and compaction of the concrete mix) and hardening zone (steam-heat treatment and secondary curing of the molded products) united between which is a transporting device, passing the prepared forms through groups of stations (striking, cleaning, lubrication and the placement of the reinforcement frames).

Manufacturing the vibro-roller at a quality of the basic moldint organ for the transfer of pressure to the molding of structural products permits the unification of three independent technological operations (pressing, vibrating and milling) into one.

This technology envisions the following sequence of operations for the manufacture of products.

The composition concrete goes through a scale batcher to the concrete mixer. Mixing lasts 4 min., after which, the mix goes into an intake hopper of the batching section. The deformed reinforcement frames are gathered at special stations, equipped with preliminary turning and laying in molds. The metal gauged form, passing by return conveyor, is loaded with a volume of reinforcement frame and passed to the vibrating table, where it is affixed by 4 electro-magnets. Into the form from the batching section the concrete mix is passed. After pouring and distribution in the form it is preliminarily vibrated on the vibrating table for a period of 60-120 sec.

A constant volume of concrete, subject to compaction by the last cylinder, is accordingly provided to the installed shears.

After the preliminary compaction of form by the vibrating table it is carried on a roller trolley, on which it is acted upon under the vibrating rollers of the driven vibrating slabbing mill with a speed of 1.5 m/min. The mill is composed of two sections. The first - four cylinders and in the second - three. The diameter of the cylinders is 700 m.m. as to the quality of the source of oscilation use pared vibrators. The length of the vibrating cylinder is 2020 m.m. The distance between the cylinders is 880 m.m. The frequency of vibration is 300 oscillations/min.

The finished form is raised from the roller trolley by a moveable lever and transferred on a trolley conveyor to the steam-heat treatment chamber. The roller trolley is returned to its original position for loading of the next form. This cycle of molding lasts about 8 min. The molded products are gathered into a packet of 6-7 each and subject to steam-heat treatment for a period of 6 hours. The temperature of the steam in the chamber is within the limits of 50-60 degrees and is maintained automatically. So that the steam may heat the entire form and slab, spacers are placed between the form, creating a space of 30 m.m.

Movement of the products occurs with the pulsating motion of the trolley train.

As the slabs are molded driving the surface down, the hardened products (attaining a strength of 200 k.g./c.m.^{2}) follow to the edger for striking. Construction of metal forms, in which the products are molded, are such as to permit lengthening of the sides to free the slabs in the edger during the period of striking the products.

After striking the form a reverse movement along the working station of the return and preparation conveyors takes place, and the slab pass into the ripening chamber for a secondary curing of 20 hours at a temperature of 20-30 degrees and a humidity of 95 %. Finally they leave for the storage area of finished products. During the hot period of the year in the storage area for humidification of the slabs use a humidifying device.

In fig. 93 the principle technological scheme for the organization of production of concrete and reinforced concrete products by the forced vibro-rolling method is shown.

The forced vibro-rolling of rigid concrete mixes, chosen of a high quality of composition, in combination with a mild regime of steam-heat treatment produces concrete products of high physical-mechanical properties and operational quality.

Studies of the influence of various technological factors have established that for concrete to attain a high density by forced vibro-rolling rigid mixes with an outlay of cement of 450-480 k.g./m^3 with V/C 0.30-0.32 are to be used . The advantageous portion of coarse dense aggregate is 60-70 % which provides high durability and non-skid properties to the concrete products. The best of these concrete are those prepared from aggregates chosen of 2 or 3 sizes. Such compositiona and high level of compaction permit the receipt of concrete of types 500-600 to Portland cement of type 400.

For the preparation of cement use coarse aggregate of 5-20 m.m., and classified sand and water resistant cement M-400.

The tests, leading from studies of the physical-mechanical properties of concrete and products, show that highway structures produced by the method of forced vibro-rolling fully answer the needs of SNeP and GOSTs, and are in line with the indeces and exceed them.

The outlay of materials per m^3 of concrete is: 450 k.g. of cement, 555 k.g. of sand, 1295 k.g. of aggregate and 155 l. of eater, which are the standards for plates having a strength limit on dropping of about 510 k.g./c.m.^{2} with a water absorption of 3.47 %. In Moscow at the Lyublinskii factory ZhBE No. 12 a forced vibro-rolling bed (fig. 94) had been installed, in which currently a mass output of solid hextaganle highway plates of the DSSh-3 type has been developed, with a thickness of 18 c.m., a long side of 116 c.m. The weight of one plate being 1.58 t. and surface of the bed being 3.52 m^2. These plates are intended for the construction of a continuous roadway surface.

for the placement of surfaces along the edge and on the axis of the roadway with a bi-sloped transverse profile make VS-4v and DS-5v semi-slab. The volume of the reinforcement frame work is made of deformed steel of the 35 GS type with a diameter of 10 m.m.

For hoisting and placement of the slab by a method without loops use cut, wedge or ZUP type clamps and make a gauged auxiliary opening in the center of the slab.

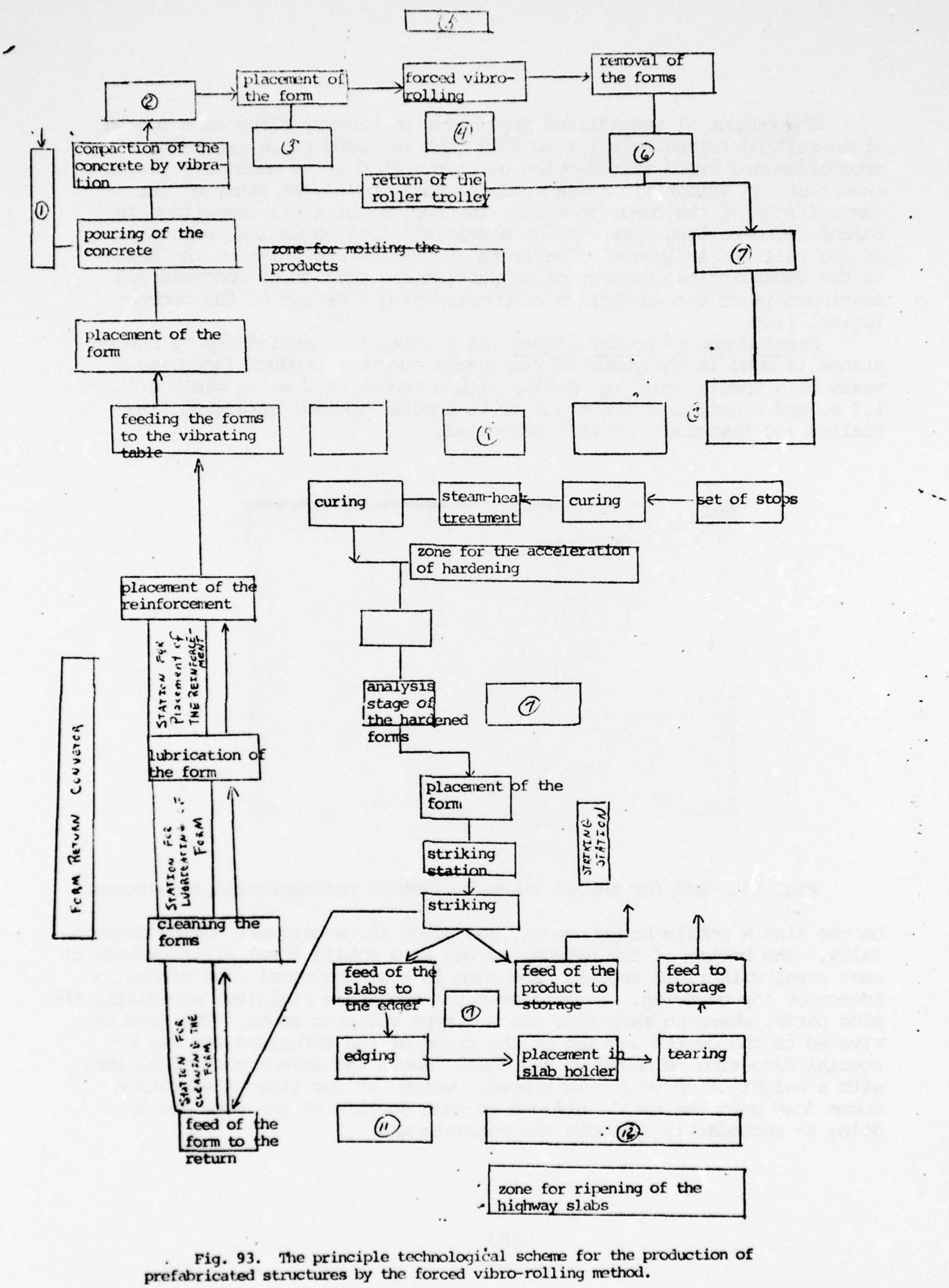

Fig. 93. The principle technological scheme for the production of prefabricated structures by the forced vibro-rolling method.

The output of specialized production of highway slabs on a forced vibro-rolling technological line show that for long range expansion of production and broad introduction of this method it is necessary to conduct thorough scientific investigation, relating to the study of the compositions of the concrete mixes, the regimes of their compaction in forced vibro-rolling beds and the acceleration of hardening, exposition of the roll and influence of separate mechanisms and units of the bed in the technological process of compaction and molding of concrete and continuation of the perfection of constructing beds and of the technological line.

Manufacture of border stones. As a rule, the manufacture of border stones is done in the yards of reinforced concrete product factories by means of a special molding machine with a length of 3 m., a width of 1.2-1.3 m. and a height of about 2.5 m. is a metal spatial structure, installed and fastened on a self-propelled.

Fig. 94. Bed for forced vibro-rolling of prefabricated structures.

On one side a mobile hopper moves, and below it, a batcher, moving horozontally. The bottom of the batcher serves as a mobile metal platform made of cast steel with rigid angles. The form is a square metal case without a bottom or top covering. It possesses the necessary rigidity, especially the side parts, where on each side one E-7 type vibrator moves. The form is riveted to the center section of the frame of the structure and may by special direction be moved up and down. Above the form a mechanical load with a weight of up to 1 t is placed, which at the time of vibration comes down onto the metal surfaces in each section of the form and by doing so secondarily compacts the concrete mix,

developing a pressure of up to 1 k.g./c.m.^{2}. The average weight of the molding machine is 5 t.

In a working situation the forms are dropped down and operated on an even surfaces. Such surfaces may also serve for asphalt or cement surfaces, along which the machine is pulled.

The concrete mix is brought by the truck loader and through the loading hopper fed to the batcher, from where it is poured in the necessary quantity into the forms. On feeding the concrete mix into the forms the vibrator is switched on. The final compaction of the mix is done by the mechanical load, placed above the forms. One unit simultaneously molds two products. After the products receive the necessary compaction, the forms are raised and the mechanism moves the necessary distance down the line of motion, to where the process of preparation occurs by that technological sequence. The productivity of this unit is 85-95 edge stones an hour.

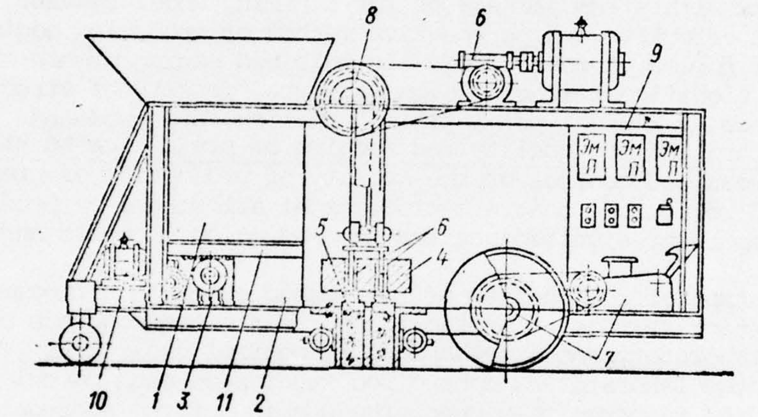

Fig. 95. Machine for the manufacture of side stones: 1 - intake hopper; 2 - batcher; 3 - mechanism for moving the batcher; 4 - load; 5 - metal forms for curbing stones; 6 - vibro-extruder; 7 - mechanism for moving the unit; 8 - electric wench; 9 - control panel; 10 - electric motor; 11 - valve over-lapping the exit opening of the hopper.

The manufacture of reinforced concrete edge stones for enclosing roadways, sidewalks and medians may be accomplished in prestressing beds.

The advantage of producing edge stones in prestressing beds in comparison with production by a molding machine is the importance of getting edging of significant length. Increasing the length of the edging stone is achieved on account of reinforcing it with prestressed reinforcement of high tension steel wire with a diameter of 2.5-3.0 m.m.

With the manufacture of edging stone in a molding machine its length is usually equal to 0.8-1.0 m. It is possible to manufacture the prestressed edging stone with wire reinforcement with the same width and height in lengths from 5-7 m.

Placing of the wire reinforcement all at once along the entire length of the bed may be done with the help of a special trolley with a reel holder, and molding the products may be organized along the lines of two methods. In the first instance the forms may be produced continually. Then after the concrete has attained the necessary strength the reinforced concrete band may be cut into separate elements of the necessary lengths.

In the second instance along the length of the form, at the necessary distance diaphrams are placed, making possible after hardening of the concrete immediate receipt of the products of the necessary length. The reinforcement between the products is easily cut after removal of the diaphrams.

Extended beds do not have steaming chambers and are intended for use with forms with steam jackets or for steaming under canvas.

The effective and perspective method of producing edging stone is the method of forced vibro-rolling. In this bed edging stones of the required profile, significant length, high strength, density of structure and with maintenance of minimal permissible variation, are produced.

Control of the quality and receipt of prefabricated structures. Correctly organized control of the quality of production of prefabricated concrete and reinforced concrete products at all stages of production has a highly important significance for the reduction of costs and of products put out.

Control of the quality of reinforced concrete structure output and their correct storage in prefabricated reinforced concrete product factories takes a laboratory and a technological control department (TCD).

In the laboratories controlled studies on each parcel of cement produced in the facotry, they check the quality of the aggregate, reinforcement and at mixture going into the concrete mix.

In the control of the porduction of concrete mix, the accuracy of the batching of materials, the stages of loading and the rotational speed of the cement mixer drum, the continual motion of the material, and the quality of the finished concrete mix are all mixed. Control of the quality of the finished concrete mix is carried out with the determination of its workability and with testing a sample cube for compression produced and maintained in the same condition as the finished product.

Checking the reinforcement is done on a control sample, testing under stress for determination of the strength and tensel limits, and for bending in a cold state and in a welded condition.

In the process of welding the mesh and the framework check the strength of the welded joints, the conformity of the diameters of the welded reinforcements,

the dimensions of the mesh and framework by diameter and size as assigned in the diagram. Before the molding of products examine and verify the assembly of the forms, the steps in their cleaning and lubrication, the accuracy of the placement of the reinforcement and the reliability of the fastening of the imbeded elements.

With the production of structures with prestresses reinforcement verify the accuracy of the placement of the stressed reinforcement along the height of the section of the product and also check the step of the stressing process.

Control of the stressing of reinforcement tendons is carried out with a PRD device (fig. 96). With its help the stress on a tendon on any diameter at any distande from the wagon and in various conditions, in the factory or in a yard, may be measured.

The principle action of the device is founded on the elastic gy of the tendon midway along it span between the supports with the help of a spring scale. Strain is measured with indicators. The apparatus is scaled to each length and diameter of the reinforcement. By the given readings a graft is constructed. The extent of stressing may be determined by conversion along the true surface of a transverse section of tendon.

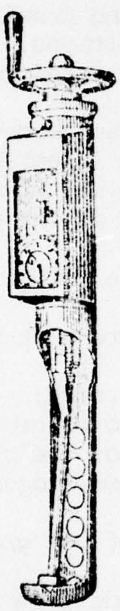

Fig. 96. Device for determination of reinforcement tendon stressing.

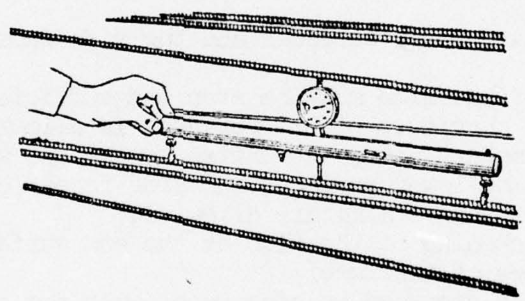

Fig. 97. PD-500 dynamometer for determination of wire stress.

The device consists of two bodies, the box with spring, the indicator, actuating screw with fly wheel clamp and support bracket. In measuring place the device with the support brackets on the cart-wagon. The clamp is placed under the rod and with a turn of the fly wheel is brought into contact with the rod. With a turn of the limb lever the tendon is prestressed to an extent, corresponding to the movement of the hand on the big scale of the indicator to 5 points. In this position, the fly wheel limb is noted relative to the

graduated line on the body of the instrument after a turn of the fly wheel one complete revolution (3,5,8, etc.) taking a reading according to the scale of the indicator. The value of the forces in the rod are found on the graph.

Monitoring the stressing of wire reinforcement is done with a PD-500 device (fig. 97), the principle action of which is analagas to a PRD device.

In the process of molding the products and in their heat treatment, check the accuracy of the sequence of plate pouring the concrete mix into molds, sufficiency of its compaction evenning of the upper surface, the regime of curing the products to their steaming and regime of heat treatment.

Before their forwarding to storage the TCD checks correspondence of the forms and the dimensions of the products, the outward appearance, the quality of smoothing of the finished products with the working drawing and the requirements of working standards and technological conditions.

The following requirements are demanded of prestressed reinforced concrete slabs manufactured in reinforced product factories:

1. Agreement of the SNeP I-B. 5. 2-62 deviations of the geometric dimensions of the finished plate from the design dimensions is established by 9th class accuracy and must not exceed in length +8, -4 m.m., by width + or - 5 m.m., by height + or - 5 m.m., and by the thickness of the protective layer of concrete +5 m.m.

2. The outward appearance of the slab must satisfy the following conditions:

On the upper and lower surfaces and the side faces there must be no cracks;

The surface of the slab must be even and sufficiently rough;

The extent of curviture of all surfaces is allowable to no greater extent than 5 millimeters along the entire lenght and width of the slab;

On the upper and lower surfaces and side faces localized ridges of a height not greater than 5 m.m. are allowable;

Localized thickening of the slab at the end surfaces of not greater than 3 m.m. (influxes of concrete);

The ends of the stressed reinforcement must not protrude from the body of the slab.

After inspection each product is classified. On the surface with a stencil or resin stamp with indelible ink mark the type of factory-producer, the passport number, the index and sort of product, and the number of the TCD inspection.

Every product, to be sent to a consumer, has an individual passport on which is stated not only the basic technological information but the guide lines for storage, transportation and slinging. The TCD controller completes the passport in accordance with the results of the determination of the cubic strength of the products and their tests under bending.

SECTION 20. MANUFACTURE OF REINFORCED CONCRETE SLABS IN YARDS

The output of prefabricated reinforced concrete products may also be organized in yards.

The basic part of yards is open, equipped with the corresponding technological and transportation mechanisms or beds, in which the molding and heat treatment of the prefabricated reinforced structures and parts is done.

Depending on the complex of buildings and structures going into the composition of yard, the complex and sub-factory yards are differentiated. Occasionally contemporary yards are built directly on the construction site near the object to be built. Complex yards are self sustaining enterprises with a complete productive cycle. The following go into their composition: Open beds, reinforcement matrices, laboratories, form and finished product storage, a concrete-solution joint with storage areas for cement and concrete aggregate, a boiler and subsidiary structures.

The lift-transport operations in the beds and in the storage area for finished products is carried out with the aid of gantry, A frame or boom cranes on rails or on roadways.

The contemporary sub-factory yards do not have their own concrete mixing point, boiler or reinforcement matrix. They receive ready mixed concrete and finished frame works from nearby reinforced concrete product factories.

The production of prefabricated reinforced concrete structures may be organized in yards along two technological schemes-the bed scheme and the production line scheme. In the first instance the structures are molded directly in the bed lines (on the ground or in semi-pit chambers) and here the are subject to heat treatment. In the second instance the structures are molded at stations, equipped with vibrating tables and are subjected to heat treatment in open surface pit-type chambers. Yards of the combined type are also built by the first technological scheme and followed by the second.

The primary method for the production of prefabricated prestressed concrete structures in beds is the heatless method with the use of quick setting cement. Heat treatment of the products is carried out by heating the concrete floor in the main surface and also steaming products in chambers.

In yards use steam treatments of the 5th type. The chambers are arranged along one or two lines, they have concrete walls and transverse partitions which separate it into compartments. The tops of the chambers are closed with heated covers.

The steam chambers in yards are usually serviced by A-frame frames. The steam is brought up in pipes, placed in closed canals. Towards the goal of reducing loss of steam and creation of hermetically sealed chambers, the covers are built with water or sand blocks at their support point on the walls and these are connected with each other.

In fig. 98 a yard plane with the bed scheme of production is shown.

The yard has two lines of beds for molding by heat treatment of the structures. The anual productivity of yard is 10,000 m^3 of prefabricated structures. The concrete aggregate is transferred from the railroad stock to the storage area with the aid of a transporter. The cement from the cars through the loading apparatus enters the silo storage. The concrete solution joint, placed in line with the storage areas of aggregate and cement, provides concrete and solution to the yard, and also provides ready-made cement.

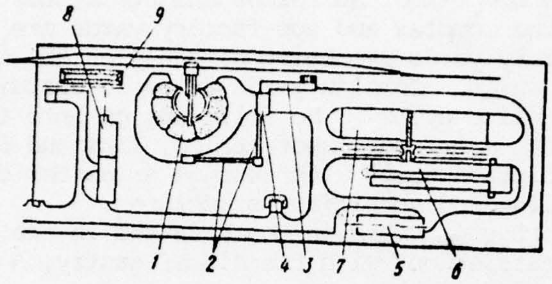

FIG. 98. Schematic Plan of a Yard for the Production of Prefabricated Reinforced Concrete Structures and Parts:
1 - storage area for the concrete aggregate; 2 - elevated platform with transporters for feeding the aggregate; 3 - storage area for cement; 4 - concrete solution shop; 5 - reinforcement shop; 6 - beds for molding and heat treatment of prefabricated reinforced concrete structures and parts; 7 - storage area for the finished product; 8 - boiler; 9 - carbon storage.

The shop works on a vertical scheme, that is, the concrete aggregate and cement are fed in a hopper, and then in a batcher and finally below into the mixing section. The concrete joint has an automatic distance control. The concrete aggregate is fed by a inclined transporter to the top story and distributed to the bunkers with a dumping apparatus. Calcium chloride, sodium chloride and sulphur- alcohol wash are introduced by pump into the water dispersing tank.

The concrete mix is fed from the concrete mixing device to the hoppers with balers with the help of electric self-propelled concrete placer cars. Every line is served by a separate concrete placer on a rail ledge.

The reinforcement workshop is placed in one building with laboratories. The workshop is equipped with machinery for producing mesh and frameworks.

By the production line scheme of production in yards the reinforced concrete structures are manufactured in metal forms

at staitions inclosed structures. The concrete mix is compacted on a vibrating table, then the structures in the forms are moved to the steam chambers of the pit-type with a multi-tiered loader. These chambers on the open ground in two or four lines.

After heat treatment the structures are struck the chambers are emptied, the metal forms are cleaned, lubricated and again fed to the molding station-the vibrating table after the productive cycle is checked. The average annual output of products of one particular worker in the yards with production lines schemes of production is almost two times greater than by the bed technology. Yards with production line technological schemes are distinguished by even greater stages of mechanization in all processes.

The intake of finished products in the yards is done in accordance with the needs of the working GOSTs, the norms and working conditions of the same as in the factories (see above).

The sotrage area for finished products in the yards is planned on the open ground with provisions for draining water, and equipped with hoisting transport mechanisms. Here the structures are stored in piles with the aid of cranes or mechanized fork lift.

The finished structures are stored in storage area in piles according to kind and type and are placed on two wooden beams sectioned roughly at 150 x 150 m.m., each element of the structure is placed on a lining of a single thickness. The linings are pulled taut vertically one under another. Placement of the structures on two or more linings, as a rule, is not allowed, because this may lead to the formation of cracks in the structures. With the correct placement of the linings the structures are not deformed , and a face between them exists for the pre-removal of the fork lift or guys for the straps.

SECTION 21. MANUFACTURE OF SILICO CONCRETE AND SLAG SLABS

Manufacture of silico concrete plates is usually carried out in stationary factories, equipped for materials, their batching and mixing, the molding of products and their autoclave treatment. In the majority of instances, factories of silico concrete products are a component part of territorial bases of construction induction. They may prepare slabs for the construction of prefabricated surfaces and foundations of with other types of structures.

The technological process of manufacturing silico concrete slabs of prefabricated surfaces envisions sequential completion of the following operations: preparation of the lime-silica binding; preparation of the silico concrete mix; molding

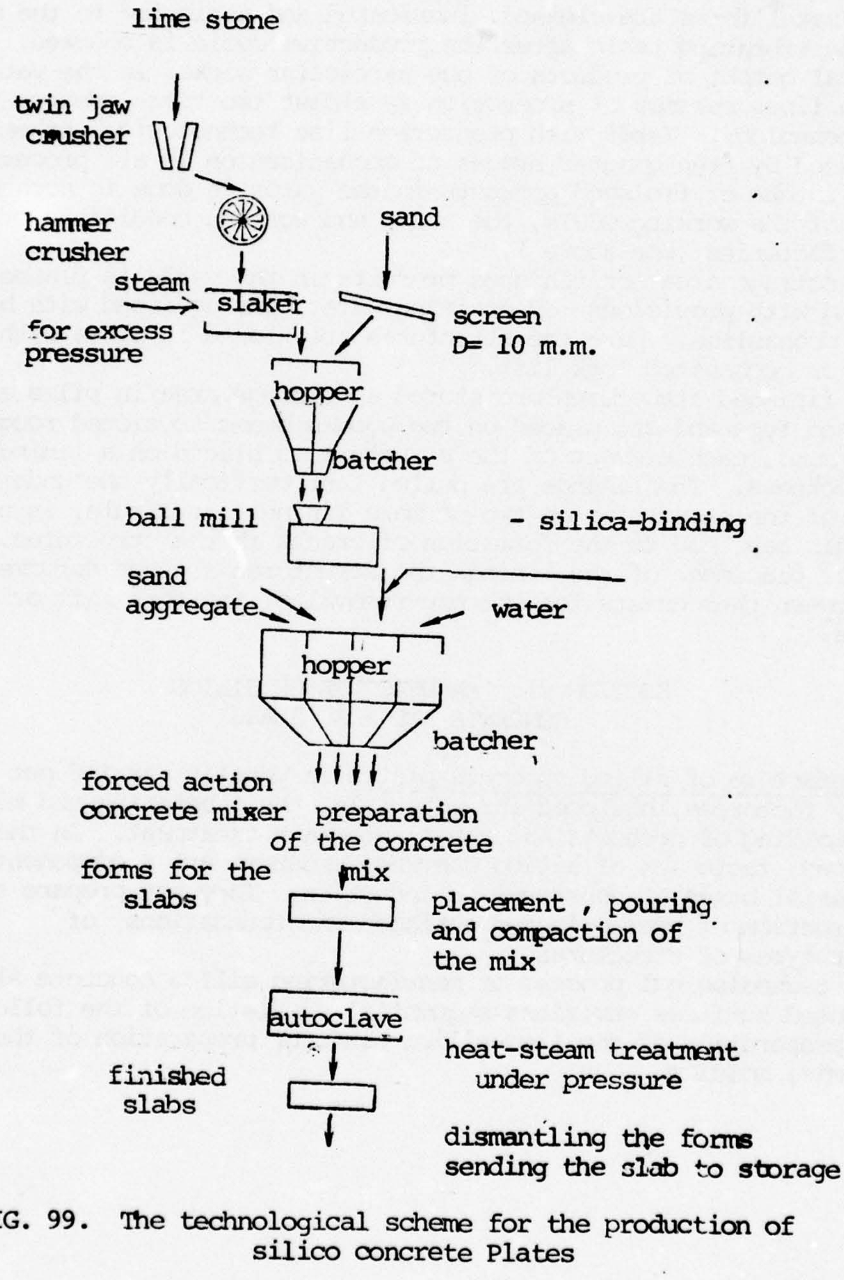

FIG. 99. The technological scheme for the production of silico concrete Plates

of the slabs; treatment of the slabs in autoclaves; dismantling of the forms and transportation of the finished slabs to storage.

An example of the technological scheme for porducing silico concrete slabs is shown in fig. 99.

The manufacture of lime-silica cementing is contained in a common thin mill for sand and lime. Before milling the rock lime is subjected to a two stepped crushing. First it is crushed in a jaw or roller cursher and then in a hammer crusher. Dimensions of the separate pieces of ground lime may not be greater than 10 m.m.

The longest technology for the processing of lime may be carried out by two separate schemes. In the preparation of the cementing for the readying of fine grade silico concrete mix the lime after crushing is subject to slaking. For the best hydration of the lime slaking is done in a closed chamber with steam at a pressure of up to 4 atmospheres. Cementing produced by this method is called hydrated. In preparation of cementing for coarse grained mixes pre-slaking of lime is not done. This method is called the boiling, and so hydration of the lime in this instance is done at the end, in the process of preparing the silico concrete mix and curing (for a period of 2-4 hours) the finished product before autoclaving treatment.

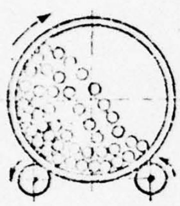

Fig. 100 Drawing of ground, sand and lime in a ball mill.

The crushed lime (by the hydrating method and slaked) is mixed with the sand in mixtures corresponding to 1:1 to 1:2. The exact ratio of lime and sand is established in the laboratory by the result of experimentation on samples of coarse lime grain silico concrete, prepared in cementings of various compositions.

Before milling, the sand is passed through a sieve with holes of 10m. m. for separation of the coarse nodules. The water content of the sand may not be greater than 2-2.5 %. It is therefore necessary to dry it in a drying drum. In the winter, frozen sand must be subjected to heating and thawing.

The combined sand and lime milling is carried out in ball mills (fig. 100). After the milling the lime-silica cementing must have remains in the sieve 0.08m.m. not greater than 8% and a specific surface of not less than 3000 c.m.^{2}/g.

The preparation of silico concrete mix is concluded in the mixing of the lime-silica cementing with water and aggregate.

Use water of a quality of not greater than 0.4 from the weight of the cementing for the preparation of surface slab, and not greater than 0.55 in the preparation of foundations slabs. The quality of lime and sand for the preparation of the cementing and the quality of the aggregate (sand for fine grain mix, sand and stone for coarse grain) is selected in the laboratory, guided by the determined needs of strength and frost resistance of the product.

Batching of all compositions is done by weight with the help of a automatic batcher.

For mixing use a forced mixing or vibro mixing concrete mixer. In using common mixers for the elevation of the quality of the mix (to uniformity) first separately mix the cementing and the water, and then add the aggregate.

The preparation of cementing and fine grain mixes may be combined into a single technological cycle with the use of disintegrators. The operating units of the disintegrator are two revolving units on opposite sides of the disc, on which are placed in a concentrated fashion in several limes cylindrical pins.

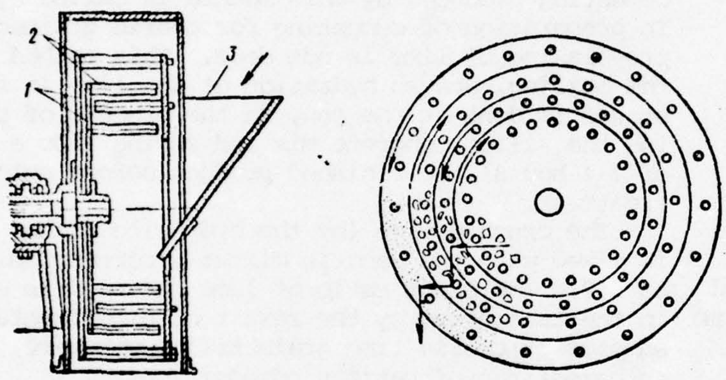

Fig. 101. SCHEME OF THE DISINTEGRATOR:
1 - discs; 2 - pins fastened on to discs; 3 - loading shute.

While revolving the pins of one disc pass between the pins of the other (fig. 101). Into the disintegrator the lime and all the sand is fed. Striking the quickly revolving pins, the materials are broken up and mixed up. In the process of mixing the mix is dampened. In the end finished silico concrete mix leaves the disintegrator. The disadvantage to this method is the significant wearing of the disintegrator pins and the nedessity of their frequent replacement.

Molding of the slabs is done in dismantleable metal forms. Feeding the finished mix into the forms must be organized in such a way that from the moment of its exit from the mixer to the pouring not more than 15 minutes pass for mix with cementing, prepared from a base of lime-silica and not more than 30 minutes for mixes with cementing from a base of hydrated lime.

Preparation of the form for pouring the mix is done in the same fashion as preparation for reinforced concrete products. They are carefully cleaned with metal brooms and high pressure water of dust and remnants of old cement. The inner surface of the form for reduction of adhesion of the form to the cement, is lubricated with various minerals

oils, black oil, tar oil, etc. In the end the lubrication of the inner surface of the form must form a continuous thin film with a thickness of .2-.5 m.m. Lubrication of the form may be replaced with covering by vinal plastic foil.

In preparation of reinforced slabs, after lubrication of the forms, place the reinforcement in them in the same orientation as the finished framework, separating the tendons or the thin wires. The requirements for maintaining the reinforcement are the same as in preparation of reinforced structures of common concrete. For protection from corrosion it is covered with an anti-corrosive coating, then the walls of the form are strengthed and placed in special supports of reinforcement cuttings, in such a way as to avert the possibility of mixing in the pouring of the mix into the form.

The mix poured into the form, is compacted by vibrations with the use of a SM-468 U, SM-176 U, SM-867 types vibrating tables, etc. The regime of vibration recommended, is that which provides a frequency of oscillation on the order of 2800-3000 oscillations/min. and an amplitude of 0.3 to 0.8 m.m. The stage of compaction is enhanced, using secondary compression from 50 -100 $g/c.m.^2$.

For increasing the quality of evenness and density of highway surfaces they are usually molded from the facing surface down. To begin with, pour roughly 20% of the total amount of mix, vibrated for a period of 30-40 sec., then fill the rest of the form, installing the cushioned load slab in continuing vibration for a period of 2.5 - 3.0 min. Such a sequence of pouring and compaction provides a good filling out of all corners of the form and a high level of evenness in the top layer of the slab.

Bi-layered slabs of material of various sizes may also be produced in this fashion. Usually, the top layer (the wearing layer) is of a thickness of about 5 c.m. and is made of coarse grain mix and the lower layer of fine grain. In this instance first separately pour and compact the coarse grain mix and then the fine grain. The regime of compaction is the same as described earlier. After compaction of both layers of the slab a dense monolith will be formed.

The molded products are subject to steam-heat treatment in autoclaves. Before the beginning of the autoclave treatment the process of flaking the lime in the lime-sand mix must be entirely completed. IN the contrary instance, that is with slaking in the autoclave, the lime will swell and defrom the product. Because of this, when using non-slaked lime for milling, it is recommended that the product be cured before being put into the autoclave for a period of 2-4 hours.

The autoclaves are horizontally alined cylinders with hermetically sealed covers on the ends. Usually they are placed in a complex of several cylinders. The number of cylinders in the complex depends on the capacity of the factory. A railway leads up to each cylinder, and continues into the interior of the autoclave. By this railway the carts with the filled forms are led up to the autoclaves.

The forms with the partially completed products (plates) are placed in the autoclaves one on top of the other in several tiers with vertical gaps between them (fig 102). The gaps must be such, so that the steam may heat each form on all sides. These gaps are formed by placing the forms on special racks.

The cylindrical shape of the autoclaves is not convenient for the placement of large sized slabs, but it is far more expedient for the retention of the internal pressure of the steam.

Industrially produced autoclaves in the majority of instances are designed to work at a pressure of steam from 8 to 12 atmospheres and at a heating temperature of up to 200 degrees C. The regime of autoclave treatment depends on the dimensions of the products, the materials used, the particularities of the forms and other local conditions. Usually this is planned in advance by reference information, and then defined more precisely experimentally. The SoyuzDrNEE for highway slabs with a thickness of up to 20 c.m., recommends the following autoclave treatment orientation regime (table 35).

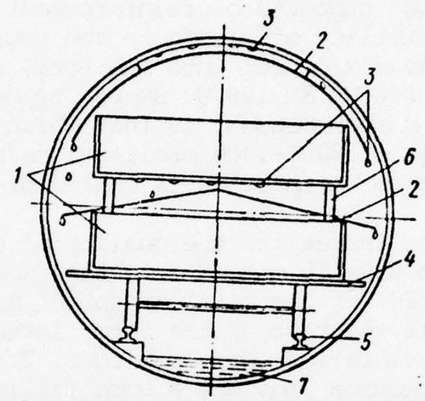

Fig. 102 Drawing of the disposition of the forms with slabs in the auto claves.

1-Forms with slabs; 2-Metal sheet protecting the slabs from falling drops of condensate; 3-Drops of condensate; 4-Trolley on which forms are placed; 5-Rails; 6-Lining between the layers of forms; 7-Condensate.

Special care must necessarily be taken in controlling the uniformity of raising and lowering the pressure of the steam and in maintaining the assigned duration of these processes. Hastening or unevenly adding and more especially, discharging steam may cause the appearance of substantial defects in the products in relation to the beginning of significant drops in pressure and temperature in the interior of the product and on its surface. The product in the autoclave may be damaged also by condensation. The temperature of the steam fed into the autoclave, in the beginning of the treatment, is always higher than the temperature of the products, form and walls of the autoclave. The steam

TABLE 35

Operating pressure in the auto clave	Auto calve processing regime, hours — Time: Increase steam pressure		Stem pressure drop	General processing, hrs.
8	1,5	10	2,5	14
10	2	8	3	13
12	2,5	6	3,5	12

the cold surfaces of the products, cools and condenses. This process continues until such a time as when the temperature of all surfaces (the products and the autoclave), that come into contact with the steam , become uniform with the temperature of the steam. The condensation collects in drops on the walls of the autoclave and the forms of the products. The amount of this is significant, because a certain amount of water gradually accumulates in the bottom of the autoclave. Of greater negative affect is the drops of concensation falling on the slabs placed below. If the products have open surfaces,this condensation may substantially damage them. For protection from falling drops covering the tops of the plates with metal sheets (see fig. 102), craft paper, etc., is recommended.

After finishing this treatment,the products are maintained in the open autoclave until such a time when the difference in temperature in the autoclave and outside is not less than 30 degress C. Then the carts are taken out, the forms are disassembled and sent to the cleaning station for the next use. The finished products are classified and transported to storage.

With the preparation of silico concrete slabs it is necessary to maintain safety technique rules, generally for all factory type productive enterprises in addition to those specifically directed for the use of autoclaves. The steam pressure in the autoclaves must not exceed the limit, specified in the passport or allowed by the boiler safety valve. Direction of the work to the autoclaves may be done only by a person, given special examination and having relevant certification. The presence of people close to the autoclaves, not having any relation to their operation, must not be allowed.

Preparation of slabs takes place on the grounds of metallergical factories (or near them) by the method of casting. With this, prefabricated - disassembleable metal forms are milled with molten slag.

The physical mechanical properties of cast slag products varies within significant bounds in relation to the chemical and mineralogical composition of the slab and also by the technology of production and in the first exposure to the heat regime of casting and cooling of the products. As a rule, the strength properties of slag are higher, having higher density. So, for slags with a combined wieght of more than 2.6 g/c.m.^{3} the limits of strength under compression is from 800 to 2360 k.g./c.m.^{2}, and under bending -from 60 to 370 k.g./c.m.^{2}.. The porosity of a piece of dense slag ranges from 7-11 %, but at the same time it posesses a high freeze resistance. Slag aggregate can survive 100-200 cycles of alternate freezing and thawing, and concrete boocks in such instances do not show signs of decompostion after 80 years of service. Last in the significant sets explaining the making of the surface of the cast slag products, is the layer of high density, with a thickness of 2-3 m.m., protecting the product from penetration by water.

Depending on the heat regime of production, the cast slag products have fine crystal and, large crystal

or vitrious glass structure. Occassionally the slag in one product has a mixed structure. In this case the vitrious glass structure usually predominates in the surface layers.

Slag of fine crystal structure has a somewhat higher index of strength. Vitrious glass slag is differentiated by brittleness, and poor resistance to compression, wear and bending.

The technological process for the production of slab of prefabricated surfaces and foundations for highway pavement by the method of casting from molten slag, curing the filled forms (cooling of the products), dismantleing the forms and transportation of the finished products to storage.

Most responsible for the determination of the structural formation of the cooled slag and afterwards, its physical mechanical properties is the curing of the filled forms. Creation of fine crystalled structured slag provides a slow and relatively even cooling of the slab throughout the entire thickness. With quick cooling, the slag acquires a vitrious glass structure and the quality of the product is sharply reduced. To provide an optimal regime for cooling then, is harder the larger the product. In order to reduce the speed of cooling of the molten slag in the forms, cover them with a protective layer of the same slag.

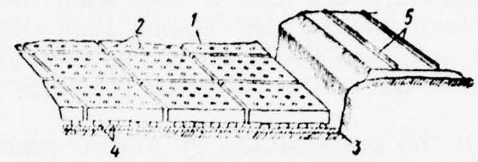

FIG. 103. SCHEME FOR THE PLACEMENT OF FORMS FOR CASTING SLAG SLABS IN A CASTING PIT: 1 - metal forms; 2 - holes in the cover of the form for pouring in the molten slag and discharge of gases; 3 - foundation of slag aggregate; 4 - pieces of slag; 5 - railway for transportation of ladle with molten slag.

The requirements of the curing regime for the filled forms must be outlined before hand, as in the preparation of forms for filling with molten slag. For casting the slag products, use a prefabricated-disassembleable form of sheet steel of a thickness of 6-10 m.m. They are placed in casting pits, situated in lines along a railway, along which travels a slag carrying ladle for pouring, which is filled with molten slag (fig. 103). The dimensions of each casting pit are roughly 3 x 5 m in the plan, with a depth of 0.6 m. With these measurements, each pit may be filled with molten slag from one standard slag carrying ladle. With a ladle of a different capacity or with production of castings in several tiers in one pit, the dimensions of it are changed accordingly.

On the bottom of the casting pit a foundation layer of slag aggregate is constructed, with a thickness of about 5 c.m. Above the slag aggregate a leveling layer (o-2 c.m.) of slag fines or quartz sand is poured. The purpose of this foundation, is to protect the bottom of the form with hot slag from quick cooling, and also to lead away rain water which has fallen into the pit.

For the manufacture of small blocks of pavement use forms without bottoms. With this directly mount the prefabricated walls on the leveling layer of the foundation of the casting pit and cover them with a cover with holes. The diameter of the holes is 30-35 m.m., the number roughly 20 per 1 m^2 of the surface of the cover.

The molten slag is poured from a railway slag car bucket into the casting pit. Through the holes in the cover of the forms it is poured completely full and additionally overflows the top of the forms, forming a top protective layer.

In the molten slag there are always gases. The quantity of them depends on the chemical and mineralogical compostion of the slag. In the period of cooling the greater part of the gases escape from the slag into the atmosphere. The exit of the gases from the slag, happening in the form, also passes through the holes in the cover. With great gas saturation in the protective layer, and occassionally in the upper part of the casting, gas pocks, are formed, the presence of which materially reduces the quality of the products. Formation of pocks in the casting is followed by an uneven rising in its surface. To significantly reduce these processes heavy weights (rails, metal castings), may be placed on the cover of the forms.

Forms for casting large products (slabs for highway surfaces) must have not only side walls and a top cover, but a bottom of metal sheeting. The bottom is built in the same fashion as the top cover- that is with holes for the passage of fluid slag. The bottom of the form is placed on separate pieces of hardened slag, situated on the leveling layer of the foundation, 30-50 c.m. across from each other. Between the bottom of the casting pit and the bottom of the metal form a face of 3-5 c.m. is formed. The molten slag, poured into the pit, fills it beginning with this space, forming the lower protective layer, then fills the form and finally, forms the upper protective layer. The thickness of the last layer is determined experimentally. Roughly, this size is equal to the thickness of the poured slab (or somewhat less).

The filled form, enclosed on all sides with protective layers of slag, are kept in the casting pit roughly 7-10 days. Lengthening of this time of maintenance in the pit, usually increases the quality of the casting, but reduces the volume of usefull production of each casting pit and each form and each by a calendar unit of time (year, quarter, month).

The dismanteling of the form is begun when the castings are cooled so that the temperature will not be different from the temperature of the air by more than 20-30 degrees. In the beginning the top protective layer is broken into separate pieces of slag with a pick-hammer. This broken slag is placed by a loader on a railroad platform and sent to a stone crushing factory for reworking into aggregate. Then the form is dismantled and the finished slab is taken from the casting pit by a crane. It is sent to storage by railway or automobile.

The disadvantage of the described technology of producing slabs is the great wear of the metal form as a result of the influence of high temperature and corrosion. Their turnover varies in various conditions from 20 to 100 cycles. With the production of pavement, the consumption of metal in forms occassionally exceeds 2 k. g. for 1 m^2 of surface finisned products.

SECTION 22. MANUFACTURE OF ASPHALT CONCRETE AND BITUMINOUS MINERAL SLABS.

Asphalt concrete and bituminous miner slabs usually are produced in yards or in shops, located on the grounds of an asphalt concrete factory or near one. For slabs, use mixes prepared in factories by conventional technology. The close move of the place of molding to the mixing apparatus allows for the reduction of transport work for the delivery of the mix to the minimum.

Work on the manufacture of slabs using organic cementing may take place all year round. However, in the majority of instances production of them in the winter, is planned , when the load of asphalt concrete factories is reduced by the output of ready made mixes.

In winter conditions it is better to manufacture asphalt concrete and bituminous mineral slabs in closed shops. But they have the same models for quick production of slabs as in hot bituminous mineral mixes in open yards.

For the manufacture of asphalt concrete slabs of small dimensions use fine grained mixes, advantageously heated.*

Though there have been instances where cold mixes have been used.

With the selection of the compositions of the mixes for the manufacture of asphalt concrete slabs, it is necessary to study several specific requirements. The hardness of the slab immediately after molding must be sufficient so that they may be taken without deforming, raised with loading- unloading and transportation works. The temperature of the slabs molded of hot mixes, varies within wide limits depending on the composition of the mix and the customary technology, though, in the majority of the instances in the end molding is greater than 100 degrees. For providing the minimal required hardness with this temperature, it is necessary to use bituminous materials, posessing sufficient viscosity in high temperatures, and also mineral materials with a high coefficient of internal friction.

The technological process for producing asphalt concrete slab is composed of two stages: preparation of the mix and molding of the slabs. Production of the mix is carried out by technology, conventional in

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* Significant research in the area of producing and using asphalt concrete slabs of small dimensions has been completed by Doctor of Technological Science, Professor AkSlavutskii (31).

highway asphalt concrete factories. Molding of asphalt concrete slab of small dimensions may be carried out by various methods. The most widely used is pressing in special presses or in presses used for the production of bricks. Pressure on the mix must be not less than 300-400 k.g./c.m.^{2}. The temperature of the mix during the period of pressing is usually maintained within the limits of 140-160 degrees. However, according to the information of several studies, low temperature limits for certain types of mix may be reduced as far as to 80 degrees. Reduction of the temperature of molding is advantageous, in as far as it raised the hardness of the molded slab. Because of this in every particular instance the optimal temperature of pressing is experimentally refined. It is known that in the same instances of production, work on compaction of the asphalt concrete mixes in the forms is done by tamping and rolling. These methods of compaction are not wide spread.

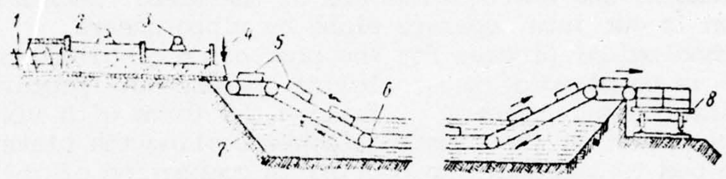


Fig. 104. Scheme for the Continuous Production of Asphalt Concrete Slabs with Compaction by Vibration and Cooling by Water: 1 - feed of the mix with slag; 2 - vibrator for advanced compaction; 3 - vibrator for final compaction; 4 - cutting device; 5 - finished slabs; 6 - conveyor; 7 - water basin; 8 - cart for the transportation of the slabs.

Compaction by vibration is the prospective by which the temperature of molding may be reduced to 60-100 degrees. Separate slabs in the form may be vibrated as a continuous line of mix from with the last cut on the slab. The scheme for the continuous production of slabs with compaction by vibration is displayed in fig. 104 (31).

With all variant technological schemes of producing asphalt concrete slabs from hot mixes maximal acceleration of the process of their cooling and attaining hardness is strived for, so that the danger of plastic deformations arising in the plate during their transportation is reduced. In fig. 104, the variant water cooling of finished plates is shown. In the wintertime air cooling may be used.

Bituminous mineral slabs of medium dimension (square surface of 3-6 m^2 and thickness of up to 16-18 c. m.) are manufactured from hot small grain bituminous mineral mixes on inviscous asphalts. The production of these slabs may be organized along the bed, production line or conveyor line technological schemes. The most widely applied, though least perfect, is the bed technology. It is used, as a rule, for production of slabs in open yards.

The bed for the production of bituminous mineral slabs is even, strictly horizontal concrete or wooden surface with a width of 3 to 9 m in a length of 100-200 m. In the bed side walls are placed creating a form for the production of the slabs. The height of the side walls must be equal to the thickness of the slab. The bed serves as the bottom of the form, the top is open for loading of the mix and its compaction.

The prefabricated-disassembleable side walls of the form may be wooden (of timber or boards) or metal (of channels). They must have rigging of the type of prongs and bolts for the secure fastening to the bed. Depending on the conventional technology, the evenning and the compaction of the mix, depending on the conventional technology of smoothing and compaction of the mix, the side walls are placed in such a way as to create separate forms for every slab or one common form in the bed for molding a band with a width and length, and short dimensions of the slab. Such a band after its compaction is cut into separate slabs by vibro shears.

The technological process for the production of bituminous mineral slabs in beds is composed of the following operations: preparation of the forms and reinforcement framework , filling the forms with mix, compaction of the mix, placement of the mounting loops, cooling the plate and movement from the bed to storage. In pouring in compaction of the mix, in the type of cintinuous band, cutting it into separate slabs takes place after the placement of the mounting loops, and before the cooling of the mix.

Preparation of the form is included in the cleaning of the dismantled parts and bed of remaining mix, placement and fastening into the bed, lubrication of them with diesel oil, filling the bottom with a thin (1-2 m.m.) layer of sand or fine dust. Wooden reinforcement frameworks are manufactured on special benches, equipped with templates. Mounting loops must be fastened to the framework. The finished framework are placed into the forms.

The hot bituminous mineral mix is fed into the forms by automotive-dump trucks or carts. The temperature of the mix at the time of pouring into the forms must be within the range of 150-170 degrees. Unloading the mix from the transportation device into the form is done carefully, in order that the reinforcement framework is neither damaged nor moved.

Compaction of the mix in the forms is one of the most crucial of the technological operations. In producing the slab in separate forms, the mix is compacted by table and internal vibrators. They are advantageously used for the compaction of mix near the side casings and in the corners of the forms. In some instances, for the elevation of the quality of compaction, it is done gradually,by layers of 5-7 c.m. The layered compaction requires corresponding distribution of the mix, which is to be previously determined in the filling of the form.

To raise the quality of compaction, combine vibration with rolling. In this instance, until the end of the vibration by the vibrating table, the thickness of the slab must be greater than the projected dimensions by 1.5-2.0 c.m. (that is, the mix must overflow above the sides of the forms by that amount). Then , the vibrators are removed, and the vibrating rollers pass along the slab, filling the bed without faces, with a weight of 1-3 tons.

The roller makes 6-9 passes on one spot, among which 2-3 passes in the beginning of the rolling are with vibrating rollers. The compaction must be completed in the period of cooling of the mix to a temperature not lower than 100-130 degrees C.

And so, the slabs are produced with the facing side up, and in the process of compaction are necessarily provided with the required evenness of this surface. The greatest damage to evenness, is the insufficiently even placing of the mix in the forms. Damage to evenness also occurs in places where the metal mounting loops are installed. These loops, join to the reinforcement framework, are used to catch the hooks of hoisting cranes. By height they are not to exceed above the surface of the slab, and it must be possible for the hooks to reach them in their places of implacement, so a small depression is constructed around them.

In the process of compaction the mounting loops occassionally move and get into the mix. These loops must be reinstated to their correct positions by hand immediately after the final compaction. The wells around the loops are also constructed by hand with a special steel hook. In some instances, it is necessary to compact the mix around the loop with small vibrators.

In molding on a bed of the continuous band variety, the hot mix may be poured by either an asphalt placer or a concrete placer. They move along special ways, laid along the sides of the form. Using the side casings of quality rail is also possible for moving the placers.

Compaction of the mix, poured in a continuous band, is done with a special vibro-compacter on a railway or by a D-136 concrete finishing machine. Cutting the band into separate slab is done with a vibrating shears, mounted on the frame, along which move the mix placers. A variant on this is the placement of the vibrating shears directly on the compaction machine.

The imperfection of the equipment in use and the insufficiency of experimentation in the productive works causes the quality of the slab, which is produced by the cutting of a continuous band of compacted mix, to drop, in comparision with the slab produced in separate forms.

Most of the time in the average continual flow of the technological process is taken up in the cooling of the slab after compaction. In the wintertime, for the natural cooling of the slab with a thickness of 16-18 c.m. from 7 to 15 hours is required, in the summer 20-30 hours. Usually, the slab is produced in the day shift, remove from the bed on the next day before the beginning of a new days shift.

In the summertime with the air temperature or in the wintertime with the necessity of accelerating the turnover of beds, the slabs are taken out at a temperature of +20-+30 degrees. Slabs at this temperature, have not acquired the sufficient hardness and are easily deformed in transportation or in piling . In order to reduce the damage to the slabs, place them in a storage area with a carefully evened floor surface. For prevention of damage to the slabs between each one in the pile pour a thin layer of sand or dust.

The transportation of the slab from the yard is carried out with a side car. Removal of the plate from the bed and loading onto the car is done with a gantry crane.

In bituminous mineral plates, produced by the bed technology (especially by the method of cutting a continuous band of mix), significant deviations in the thickness of the slab (up to 1-2 c.m.), and also insufficient compaction of the mix around the sides and in the corners has been observed. In the event of the insufficiencies they must be called to the attention of the engineering and technical personnel.

Manufacture of slabs in closed specialized shops usually is carried out by the production line or conveyor line technology. With the production line technology, molding of the slab is carried out in separate prefabricated-dismantleable forms, with compaction on a vibrating table with a load (fig. 105). From the vibrating table, the finished slab in the form is sent to a intermediate storage area for cooling.

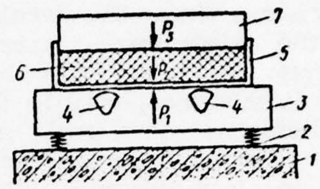


FIG. 105. COMPACTION OF BITUMINOUS MINERAL SLAB ON A VIBRATING TABLE: 1 - foundation; 2 - spring; 3 - vibrating table frame; 4 - electrocentrics; 5 - the form; 6 - the compacting slab; 7 - the load P_1, P_2, P_3 - guided compaction force.

In the event of a source of water of sufficient quantity around the shop, cooling of the slab may be significantly hastened with the loading of the slabs into a basin with running water. In this instance the length of cooling is shortened to 1-2 hours.

The technology considered most perfect, is the conveyor line method, with driven equal measured rhythm of movement of the forms and materials along the technological line. Molding the plates in these instances is carried out by various rolled carousel beds. Compaction by rolling, in its effect on the mix, is analagous to the effect of rolling. The difference is that in the rolling band the roller is immovable and the form with the compacted mix are moved.

The scheme for the rolling stand is shown in fig. 106*. The extended stand is constructed under the discharging shute of the asphalt mixer. The mix falls of its own weight into the metal cart (form) 1, which is moved by a wench 2. The mix is leveled with a surfacing plane 3, and is acted upon under compacting cylinders 4. The alternating motion of the surfacing plane and the cylinders envisions the settling of the mix under compaction to one third the height of the uncompacted layer. The final size of the settled mix is precisely determined in the course of production. The position of the surfacing plane and the cylinders are to be regulated by height. On an experimental sample stand (in the city of Omsk) such regulations has allowed preparation of slabs with a thickness of from 10 to 20 c.m. with the established dimensions of the slab in the plans of 174 x 299 c.m..

*Machine designer V.A. NIKISOROV.

The quality of compaction of the mix is substantially raised with the inclusion of a vibrating table into the technological line before the cylinders. On the vibrating table the filled forms undergo advanced compaction. The final compaction is provided by the cylinders on the rolling stand.

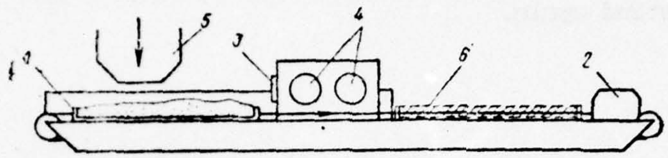
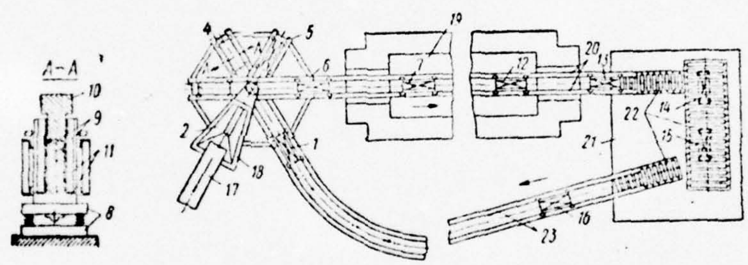


FIG. 106. SCHEME FOR THE ROLLING STAND FOR THE PRODUCTION OF BITUMINOUS MINERAL SLABS:
1 - cart (form) with mix; 2 - wench; 3 - surfacing plane; 4 - compaction cylinder; 5 - shute ffrom the asphalt mixer; 6 - position of the form with the slab after compaction.



PIG. 107. SCHEME FOR THE CAROUSEL MOLDING STAND FOR THE PRODUCTION OF BITUMINOUS MINERAL SLABS OF SMALL MEASUREMENT:
1 - placement of the form on the vibrating table; 2 - compacted form with mix; 3 - placement of weight; 4 -- compaction on vibrating table with weight; 5 - removal of the weight; 6 - removal of the form from the stand; 7 - cooling of the slab in a water basin; 8 - vibrating table; 9 - slabs; 10 - weight; 11 - vertical rack; 12 - 13 -moving slab from the basin to the striking area; 14 - striking of the slabs; 15 - lubrication and fabrication of forms; 16 - feed of the forms to the stand; 17 - conveyor for feed of the mix; 18 - hopper for mix; 19 - bath for cooling the slab; 20 - load way; 21 - area for striking and preparation of form; 22 - roll way; 23 - road way (with switching points for guiding the return of the stands and the movement of the forms).

For manufacture of bituminous material slabs of small sizes (50x50x6 c.m.) use carousel molding stands* (fig. 107). Forms of the vertical framework type are placed vertically and on a closed sextagon. In every form several slabs may be simultaneously produced. At the six stations of the carousel stand at one time or another the six various operations of placing the prepared form on

* Machine designer A. S. ROSTOVTSEV.

the stand, filling it with the mix, placing of the weight, compaction by vibration, removal of the weight, and removal of the form with the slab from the stand are carried out. Afte completion of one operation the stand moves around 60 degrees to the next station. The duration of the completion of all operations equally takes 3 minutes.

Operations on the cooling of the slab, the reassembly of the forms and their preparation for the next cycle takes place before the duration of the carousel stand cycle.

CHAPTER 5

ORGANIZATION AND TECHNOLOGY OF BUILDING PREFABRICATED HIGHWAY SURFACES

SECTION 23. THE BASIC SITUATION OF THE ORGANIZATION OF WORK IN THE CONSTRUCTION OF PREBABRICATED SURFACES.

Design construction decisions, the technology of productive work and its organization are closely interrelated.

In the area of construction of prefabricated surfaces the following examples of interdependency of organization, technology and construction decisions may be brought up. In working with structural slabs, it is necessary to observe the conditions of uniformity and standardization in weight of one slab and the weight capacity of available means of transportation. Such uniformity may be provided in two ways: designing the slab in relation to the weight or choosing the means of transportation by the requirements of the weight capacity. On the other hand, the poor use of the means of transportation would inevitablly lead to a increase in price of transportation work. By means of the second example, the dependence of the choice of materials for the completion of joints in the prefabricated surface depends on the time of the productive work. With the organization of construction in the wintertime, it is not recommended that the joints be filled with cement composition, because their freezing significantly reduces their strength.

The more complex the productive work, the more significant is its level of organization. Currently, in road construction, the majority of work is mechanized and automated. In these conditions the productivity of collective labor in road construction sub-division and the rate of their completion of work, is divided first of all, by the organization of the complex use of all available resources.

The entire process of building prefabricated structures is divided into 3 steps: first - production of the element (slabs), second - transportation of them to the place of use, third - mounting of the prefabricated structures (prefabricated surfaces or foundations). Coordination of these steps may, in time, occur by severl principly different organizational schemes. The greatest labor consumption denotes the first two steps - preparation of the slab and its transportation. The work of the third and final step requires less labor and energy out put. But in quality, the completion of these tasks in the last analasys, depends on the quality of the prefabricated surface (its evennes, its workability, its water resistance, etc.). Organization of the mounting work in this line of events, is determined by the time limit for construction. At the same time

the technology of mounting slabs has been developed still insufficiently, and in its own way the level,(above all, in the tempo of production and the provided quality) has significantly fallen behind the technologies of other types of work.

Manufacture of slabs in the majority of instances is expeditiously divided into self sustaining productions. The following basic variants in the organization of the manufacture of slabs are possible.

1. The slabs are manufactured in stationary factories with large capacities during the entire year. The factories specialize advantageously in the production of slabs of prefabricated surfaces and foundations of highways. All work is mechanized, frequently automated and carried out in closed separate shops with high capacity high quality equipment, providing a combination of high productivity with precise observence of the requirements of the quality of the work. Organization of such specialized factories is expeditious with a high volume of highway construction, planned on a multi year perspective and concentrated in the area of one territory or one region.

2. The manufacture of slab is included in the output plan of production of enterprises with a multi-branch base in the construction industry. The output of highway slabs is conducted simultaneously of parts and structures for housing, industrial and other types of construction. This variance may be carried out at a location near the object of the highway construction, well developing the basis of the construction industry with the necessary reserves of production capacities. The expense of the slabs in this instance is usually minimal. At the same time in such enterprises, it is not always possible to provide fullfillment of all special needs, in the production of products used for the construction of highway pavement.

3. Production of slabs may also take place in shop or in yards, organized with vactories of ready-made mix (concrete, bituminous material). A large part of the concrete or bituminous mixes are used for the constriction of monolithtic road pavements. Simultaneously part of these mixes are assigned to the production of slab. This variant of organization of porducing slabs usually is carried out with the undertaking of small volumes of construction of prefabricated surfaces or foundations. By this method, it is possible to use various sub-variants in factories during the course of the year:

Factories working only in the summertime and accordingly only in that period produce slab;

Factories working yearround, but in the summer producing mixes only for the construction of monolithic pavements, and in the winter only for the production of slabs, etc.

4. In some instances road construction organization plates are produced in special structures for this purpose (in yards). Such units are usually located in direct proximity to the road under construction, so that the cost of transporting the slabs may be materially reduced. At the same time,

the cost of producing the slab at these units is usually somewhat higher.

With the comparative technical economic estimations enumerated above, for the variance in the manufacturing of slabs for prefabricated surfaces and foundations the option is usually for the specialized stationary factories with multi-year limits of operation. They are usually equipped more completely and have a higher productivity of equipment, thanks to which the accuracy of sorting and the batching of discharged materials is increased, and so is the uniformity of the mix. Use of stock rigid metal forms provides molding of slabs with a high level of compaction and accuracy observable in all geometric dimension. In factory production better conditions for the complex mechanization and automation of all technological products exists.

The cost for producing slab in contemporary operating factories with low productivity or in open yards is always significantly higher, than in major stationary specialized factories. Because of this the production of slabs by this method follows only in those instances, when for some reason it is impossible to produce them for the task design, in the major specialized enterprises. Such a situation may arise in particular with a significant distance separating the road under construction from the stationary factories. In this instance, the economy for producing the slabs is often insufficient for compensation for the higher expenditures for transportation.

Because of this, in order to reduce the cost of the slabs, produced in enterprises of the contemporary type and with small capacities, it is envisioned that in theses factories and yards simultaneously other products and parts necessary for the construction of roads: bridge parts and pipes, guard rails and beams, road signs and home components, etc. will be produced.

The transportation work, serves as an intermediate link, relating the production of slab and the mounting of finished surfaces into one construction process.

The shipping of the slab from the factory is usually done by automotive vehicle. Large scale plates are often shipped by special means. In separate instances the slabs are transported great distances by railroad or by waterways.

The necessity for transportation means in the construction of prefabricated surfaces is very significant. It has sharply grown with the enlargement of the size of the slab. The cost of transportation has, accordingly, also grown. With large size slab the cost of production is increased by the cost of transportation.

The expeditious developemnt of the organization of work of all transportation means and servicing them with loader and unloader machines is a difficult task. In line with these occurrences, providing optimal organization has made necessary, making changes in the previously planned organization of the production of slab and their placement. At the same time the organization of the transportation of finished slabs has had significant advantages over the organization of the transportation of

cement-concrete or hot bituminous mineral mixes, used for construction of monolithic surfaces. The distance and rate of speed of the transportation of mix is rigidly organized within limits of time according to hardening (for concrete) and cooling(for hot bituminous minerals). The length of time and distance of transportation of the finished slabs is organized according to technological needs.

The organization of transportation of slabs is determined by economic expediency, and also by the prescense of the necessary means of transportation. Sending the slabs to the place of implacement may be done as continuouslly as the movement rhythm of the factory. In the past few years better use of trnasportation in scale of all production has been permitted, that is there is no necessity to change the number of automotive vehicles engaged in the transportation of slabs, so, in changing the distance of travel free side cars may be used for the transportation of plates all of the time.

One may change the volume of transport work by the time of year. In the majority of cases, transportation in road construction is loaded unequally during the course of the year. More required transport in the summer, less in the winter. Besides this, in the winter often it is possible to attract to road construction, a large number of transportation units from different areas, which make possible the execution of mass transportation of slabs over significant distances. This circumstance may be furthered, so that the slab may be immediately mounted on the roadway or temporarily stacked in piles near the construction of the future prefabricated surface or foundation.

It is possible to use the following basic variants of the organization of transportation of slab from the factory-producer to the place of use. These variants are characterized by the inter-relationship between the transportation and loading and unloading work and show the dependency on their organization from placement of the storage areas and to the particularities of road mounting construction work.

1. The slabs are transported to the place of constructing the prefabricated surface (foundation) immediately after production and with "koles" are placed in their assigned locations . The advantage to this variance is,that their is a minimal amount of loading and unlaoding work, the necessity for building intermediate sotrage areas is eliminated, the time during which the means of trnasportation are diverted to preparation work is abbreviated.

Executing transport work by this variance is possible only with the precise coordination (by the hour and even by the minute) of the work at all points of the productive process - at the factory, in transportation, in placing machinery, etc. Divergence from the charted motion of the automobile is invariably related to divergence from the normal rhythm of work.

The rhythm of work in the mounting of prefabricated surfaces is completely dependent upon the rhythm of the discharging of slabs to the place of their positioning. At the same time, unfilled plan norms in the placement of the plates will cause a back up in the unloading machinery.

The number of required automotive vehicles is determined by the distnace of the trip and,the productivity of the factory and the readiness of the slabs. Because the distance of the trip changes as the construction moves forward, the requirements for automobiles also changes. Partial changes in the requirements for the number of machines, engaged in the transportation of slabs, materially complicates the organization of the transportation work.

In mounting with "koles" the crane placer lifts the slab off of the automobile and places it immediately into position. With this organization of the work, the necessity for secondary cranes for the unloading of the cars is eliminated. At the same time, if the automobiles (or automobile train) has transportated several slabs, the absence of special unloading machines may lead to a significant increase in the idle time of the transport means, because the time required for the combined unloading and placement of the slabs, is always greater than the time required for unloading.

Enumerated reasons (the dependence of the rhythm of work in the factories and on the road on the precisness of fullfilling the planned transportation work, the requirements in a changing number of automobiles and increase in their idle time in unloading) leads to the conclusion that, in practice road construction frequently does not permit the organization of transportation work in a similar way. Though it ought to be noted that application of the given variant in the mojority of instances provides the maximal economic effect.

2. The more widespread variant of the organization of transportation is that in which the slabs, after production are sent to the factory storage area. The discharge of slabs is determined by the measure of the requirements for them in the place of their implacement. With this, secondary expenditures for the construction and operation of factory storage areas arise (in comparison with the first variant). The advantage envisioned by this variant is in the substantial reduction in dependency of the organization of transportation and the construction mounting work on the charted productivity of slab in the factory. So, for example, the factory may prepare slabs in the winter and send them to where they will be used in the summer. Or the factory may work in two shifts, and the slabs will be sent out in only one, etc.

The rate at which the slabs by disorganization of transport work are sent out, is determined by the rate at which they are placed. In some instances at the location of placement a secondary crane for unloading is used. With its aid, the slabs are unloaded at the road side, and they are placed on the surface by a special crane placer. Usually the unlaoding of slabs goes on such an organization is related to the expenditures in the operation of unlaoding cranes, but abbreviates the waiting time of the automobiles on unloading, reducing the dependence of the construction mounting work on the rate of slab shipment and permits freer useage of various technological schemes of placement.

3. The finished slabs are moved out of the factory storage area to an intermediate on line storage area. The latter is built on either at the end of the road

or on the side. In one intermediate storage area a number of slabs, sufficient for the construction of about 2-3 k.m. of prefabricated surface or foundation are stored. This variant is usually applied in the event of using in the period of a very short time a large number of transportation means. In this instance the discharge of plate to the intermediate storage area significantly outstrips their placement on the road pavement.

The transportation work not related to the rate of slab output, or rate of placement exists by an independent charting, frequently changed in rate, depending on the alterations in distance of travel and the availability of means of transportation.

As before, the slabs are sent from the intermediate storage area to the place of positioning by accounting of their need at the location of construction. Accounting for the insignificant between the intermediate storage area and the place of work, the stream of construction of prefabricated surfaces, the mounting of the latter is organized, as a rule, with"koles".

With this variant, it is necessary that secondary loading-unloading equipment serve at the intermediate storage area for the delivery of the slabs, as at the final unloading at the location of placement. Besides this, it is necessary to have the secondary transportation equipment for the movement of plates from the location of implacement to their mounting. The quantity of these transportation means is usually not great, but they are used non-effectively for transportation over small distances and with great waiting times in loading and unloading (in a per cent relation to the entire work time).

At the final step of construction the work of mounting the prefabricated surfaces (foundations) of finished slabs is performed. This work is organized on a line method, independent of the particularities of conventional variance of organizing the work of production and transportation of the slabs.

The uniformity of the work throughout the entire length of the line, the full interchangability and relative simplicity of productive operations, completed directly at the place of implacement, this is the particularity of construction and technology of prefabricated surfaces which allows the organization on the road of an effective production flow. In its own turn, the organization of work by this method allows in the course of production more full utilization of several advantages of prefabricated surfaces: the possibility of quick implacement in the operation of the final processes and the transportation of materials which are finished products. For the use of these advantages it is necessary to plan the guidance of the productive flow by the placement of the slab from the factory producer.

Production work by the two methods, in additional to the common disadvantages, has a material inconvenience (it is impossible to provide junctures of separate fine parts of surface with the entire standard slab. Such junctions necessarily are made with monolithic concrete or to fit finished slab through the measurement of the needed face in the surface.

The general process for mounting prefabricated surfaces is composed of 3 basic technological operations. Preparation of the foundation, placement on it of the slabs and sealing of the joints and junctures.

All work of mounting is characterized by a high level of mechanization and low labor consumption and energie consumption in comparison with work on analagous structures of monolithic construction. Placement of slabs of both and large and medium dimension is done with various cranes. Frequently equipment designed specifically for loading and unlaoding work is used for this purpose. In the majority of instances, the crane designed for this work, can not provide the high rate or necessary quality of placement of the slabs. Specifically, they cannot provide the accuracy in placement of the slabs by the designed height marks, which materially reduces the evenness of the prefabricated surface. Though currently we do not as yet have the output by industry of the complex means of mechanization intenede specifically for the placement of slabs and the finishing of joints between them. In separate cases various slab placing machines are used, having been developed and produced experimentally.

In the placement of slabs of small dimensions (with a square surface of 0.25 m^2 and less) the process still must be done by manual labor. This circumstance is one of the principle reasons for limiting the use of slabs of small dimension.

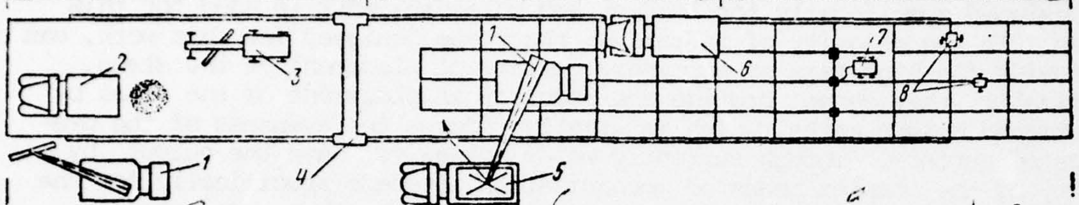
Sealing the joints and junctures between the plates is done with a mechanized instrument.

In fig. 108 an example of the technological scheme for construction of a prefabricated surface from reinforced concrete slabs is shown. Adoption in it of the technological sequence of production work in the majority of cases is preserved as with the construction of prefabricated surfaces of other slabs.

The detailed questions on the technology of mounting prefabricated surfaces are set forth below.

The complex scheme for organizing the construction of prefabricated surfaces is the result of uniting parts of variant organized work into separate stages, that is production, transportation and mounting of the slab. At the basis of such unification must be the situation of agreement and intercoordination of action of all production transportation and building-mounting sub-division of this method, in order to provide the completion of construction in the assingned period of time with the best demonstrable use of all types of resources and the maximum economy of effect.

In the majority of instances the speed of the flow of construction-mounting work on the road, is determined in relation to the norm of the duration of construction (or the assigned deadline for its completion), represents the basic perameter determining the rate of preparation and transportation work. In some instances the dependency may be reversed, that is limitations of the capacity of the enterprise producing the slab determines the speed of the flow of mounting the prefabricated surface.



	Preparation of the foundation	Placement of the slab	Sealing of the joints and junctures
types of work	1. Placement of the rail-form. 2. transportation of sand, going into the asphalt for construction of a leveling layer. 3. advanced sifting of the sand in an automatic grader. 4. final placing and compaction of the leveling layer by a profile rolling machine.	1. transportation of the slabs. 2. placement of the slabs by a self propelled crane. 3. Vibro-placing of the slabs.	1. welding of the reinforcement in the joints of the slab and junctures of the trenches of concrete mix. 2. filling the joints with resin-asphalt mastik. 3. stripping the rail-form.
means of mechanization	1. self-propelled crane for the placement of rails-forms. 2. automotive roller. 3. auto grader. 4, creation of profile in foundation.	1. automobile for the transportation of slabs. 2. self propelled crane for unloading the automobile and placing the slabs. 3. vibro placing machine.	1. welding unit 2. pouring joint 3. self-propelled crane (which is the same as 1-e clamp).

FIG. 108. EXAMPLE OF TECHNOLOGICAL SCHEME OF PRODUCTION FOR THE CONSTRUCTION OF PREFABRICATED SURFACES OF REINFORCED CONCRETE SLABS:
1 - self-propelled crane; 2 - automotive roller; 3 - auto grader; 4 - profiling apparatus for the foundation; 5 - automobile for transportation of the slabs; 6 - vibro placing machine; 7 - electro-welding unit; 8 - pouring the joint.

however, in these consitions it is possible to provide a high speed of the construction flow on account of advanced (to the beginning of the work line) transportation of the slabs to the road.

The interrelation between the productive enterprise (factory, shop, yard) and the construction flow of mounting the prefabricated surfaces is characterized by the following equality:

$$P_{ez}t_{ez}K'_{sm} \geq vNt_mK''_{sm}, \tag{171}$$

where P_{ez} is the shift productivity of the enterprise in the production of plates in units per shift; t_{ez} is the duration of work of the enterprise for the production of a slab for a given road, in working days; v - is the shift productivity (speed) of the productive flow of mounting the prefabricated surface in k.m per shift; N - is the number of slabs, necessary for construction of 1 k.m. prefabricated surface; t_m is the duration of action of the construction flow, in work days; K_{cm}', K_{cm}'' are the coefficients of the shift of the enterprise and construction flow.

The equality (171) may be used for decisions on the organizational task in greater application in practice in road construction situations, when the prefabricated surfaces are placed in one line, provided with slabs from one enterprise. With a more complex system (several enterprises producing slabs for several different productive lines) the question of optimal placement of factories and attaching to them the construction parts of roads, are decided by more complex methods (for instance methods of linear programming). By the equation (171), knowing the productivity of the enterprise, it is possible to determine the minimum necessary time for its work, or, with the limitation of that time, the maximum possible speed of the construction line.

With the working out of plans of production for the enterprise and the construction line it is necessary to note the time of their action characterized not only in number of working days (duration), but in calendar limits which begin and end each aspect of the work (manufacture of the slab, its transportation and mounting). The limits in their turn will depend on the weather conditions in the area of construction, fulfilling the deadline of the flows of fundamental materials, the accuracy in fulfilling the plan for transportation work by moving the initial materials to the enterprise and the finished products through the road, the level of technological readiness for the application of equipment etc.

In relation to the designs for the organization of work, possibility of some variation in the time limit ought to be envisioned, and taken into account. Usually they are determined with good accuracy, the very early and very late beginnings and end of each type of work in relation to the possible calendar limits.

The equality (171) is accurate on the condition that the calendar limits of production and mounting the slabs will be limited by the following conditions; the latest possible deadline for the beginning of the production of the slab is not to be later than the earliest limit for the beginning of the mounting of the prefabricated surfaces; the latest limit for the finishing of the production of all slabs necessary for the construction of the designated road, may not be assigned later than the earliest limit for the finishing of the placement of the slab.

For example coordination on a calendar graft of the limit of the productive work of producing the slabs and their placement in the surface is given in fig. 109. The continuous line 1 shows the greatest possible graft of action of the flow in the placement of the slabs. The dotted lines 2 show the limits of possible influence from weather conditions. The dash dot line 3 shows the accepted given situation on the graft for the production of the slabs in which the process of making the slabs ought to outstrip the work on placing them by two months. The band, limited by lines 4 show, within what limits the deadline for the manufacture of slabs may change.

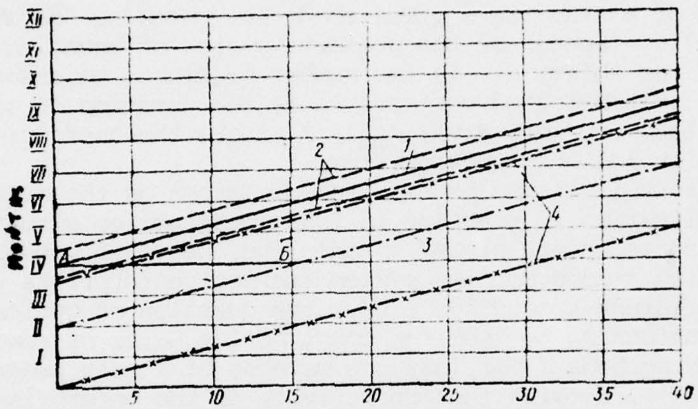


FIG. 109. SCHEMATIC CALENDAR GRAFT FOR THE PRODUCTION AND PLACEMENT OF SLABS:

1 - the greatest possible graft of the action of the line for the placement of the slab; 2 - the line of the earliest and latest possible deadlines of action of this productive line; 3 - the greatest possible graft for the production of slab; 4 - lines of the earliest and latest deadlines for the production of slabs.

The productivity of the enterprise on the graft is accepted to be equal to the productivity of the line of placement. With sufficient quantity of transportation devices the slabs may be placed as with "koles", as in from earlier plaecement in intermediate storage areas. The number of slabs in the storage area are characterized by a horozontal line between the lines of the graft for production and placement. So on the graft line ab shows that before the beginning of work in May, in the storage areas were 15 k.m. of finished prefabricated surface.

The final choice in the general scheme of the organization of all the entire production of prefabricated surfaces (foundation) is done by a technical-economic comparison of all variants, possible in a given construction situation. The method of approsimating various variants is set forth below.

24. SUBGRADE PREPARATION AND SLAB LAYING

The construction of a road bed followed by the arrangement of a precast concrete wheel track (or subgrade) shall be done according to the Soviet Norms and Standard Code, which is also valid for the construction of regular cast-in-situs pavements.

Precast sectional surfaces of temporary roads (regular track type) which are designed for a short life are laid right on the subgrade soil in a number of cases. Before the surface is laid the upper course of the road bed must be thoroughly levelled and consolidated. Regardless of this, however, because of lack of stronger subgrade (as compared to road bed) as often as not erratic sagging of individual slabs can occur on temporary roads.

In practice such occurrences are sometimes considered to be admissible considering the small volume of transportation and short life of pavements of temporary roads, and provided they are designed for cargo haulage at relatively low speeds. If the sagging is considerable, the slabs are lifted and placed anew following the repair of the road bed.

As to the precast pavements of permanent-type automobile roads, no slab sagging can be bearable under traffic. Therefore, precast permanent-type pavements are laid on special subgrades ensuring the slab stability under traffic. The subgrade thickness rating is done based on conditions that the pavement deformation resulting from traffic must not exceed the limit of elastic deformation.

The materials to be used for subgrades of precast pavements are sand, gravelly sandy materials, broken (crushed) stone or chips, slag, reinforced soil, etc. The standards of strenght, stability, compactness and cold resistance of materials to be used for the construction of prefabricated pavement subgrades must be equal to those of the similar courses of cast-in situs pavements.

Slabs of pre-fabricated rigid pavements (concrete, reinforced concrete, cast slag and silicate concrete) distribute the force of temporary loads throughout a considerable bed area. The specific loads on the subgrade under the precast rigid pavement are relatively small (as well as under the cast-in situs rigid pavement). However, regardless of the fact, the precast pavement subgrades must have a uniform strenght and compactness throughout; or else, erratic slab sagging may result, bringing about the detrimental effect on the road pavement smoothness or, sometimes, its total collapse.

The precast pavement subgrades must also be highly water-resistant. In violation of the existing standards for waterproof joint sealing, in real practice the performance of precast pavements leaves much to be desired, and moisture does penetrate through the joints to spoil the subgrade. Local subgrade over-moistening under the joints contributes only to the detriment of its strenght and growth of plastic deformations. Thus the homogeneity of the subgrade properties is disrupted, and no contact of the subgrade with the slab bottom surface remains intact. Also, under the influence of the

traffic over the pavement the slabs may be displaced or their edges may be broken. In order to rule out this occurrence, firstly, it is necessary to fill up the joints with water-resistant materials, and, secondly, it is a must to provide water-proof subgrades.

Practice shows that subgrades made of broken (crushed) stone, gravelly material of optimal composition, as well as soils reinforced with cement or bitumen are the most stable and lasting ones. Sand subgrades are also very widespread in road construction. However, they have very serious drawbacks. Subgrades made of pure coarse sands only more or less meet the standards of modern road construction. Subgrades made of fine and impure sands do not possess any sufficient standard water-resistance. In case water penetrates the joints, such sands become very thin. Under the pressure of heavy vehicles on the road the slab ends sag and the thin liquefied sand is "splashed" through the badly sealed joints. The sand ejection from under the slabs in the joint area still more sorsens the slab performance and results in loosening and displacement of the slabs, first, and their complete collapse, afterwards.

It should be pointed out that a very important condition for the normal slab performance under load is provision of a tight contact throughout the subgrade area with the slab bottom surface.

During the construction of cast-in-situ pavements of concrete or bituminous-mineral mixtures the job must be designed as road-mix construction. The mobile mixtures must fill up all unevenness of the subgrade, which is designed to provide a tight contact and an immediate load transfer from the surface course to the subgrade in any point following the packing and solidification.

Any deviations available on the subgrade in contradiction to the preset vertical markings, transverse and longitudinal gradients can be rectified to some degree with the material of the upper course, although it will involve the excessive spending of a more costly material of the pavement.

If laid on an uneven subgrade, the rigid slabs rest only on its elevated sections. Under load such slabs generate stresses exceeding those designed. Excessive local stresses can also be observed in slabs laid on an unevenly packed subgrade. Practice shows that cast-in-situ pavements performance displays a great deal of failures (disintegration through cracks) of rigid slabs laid on an insufficiently even or unevenly packed subgrade.

Research (conducted by Prof. Magilevich) showed that any unsatisfactory (interrupted) contact of precast pavement slabs with the subgrade, as well as an unevenly packed subgrade can result under unfavourable conditions in the growth of local stresses in the rigid slabs by 50 to 100%. In those cases when the established procedure of work does not ensure the necessary contact between the pavement and the subgrade throughout the area,

and there is no trace of a high and homogeneous compactness of the subgrade, the designed stresses in the slabs must be increased, multiplying by the coefficient of nonuniformity of the subgrade R_n, whose value is taken 1.2 to 1.5

However, during the course of construction work it is necessary to set the goal at meeting all the standards of the subgrade evenness and compactness so as to rule out any trace of appearing excessive local stresses on the slabs. Taking into account these stresses in the course of the slab design usually results in the increase of material consumption per unit area of the subgrade and its excessive cost. As an exception, it is possible to lower the standards set for the subgrades of precast pavements on temporary roads with light traffic and a short life.

Non-rigid slabs (bituminous-mineral and asphalt concrete) laid on an uneven subgrade have a tendency to deform gradually and stick very tightly to the subgrade, but in this case the pavement evenness and smoothness deteriorate a great deal.

Therefore the subgrades of both rigid and non-rigid types are always set the standards of high evenness and uniformity of density. These qualities are most easily achieved on a sand subgrade. The possibility of its rectification during the course of slab laying allows to attain a good contact (abutting) of slabs with the subgrade. If the construction materials are metal gravel and reinforced soils, no standard contact or abutting is attained between the subgrade and the slab bottom surface. In order to be able to plan the subgrade surface and to provide a better contact with the slabs, provision is made of a special levelling course of a slight thickness (2 to 5 cm) made of fine loose materials.

These materials are chosen depending upon the design and designation of the pavement. In this case "black sand" (sand treated with liquid bitumen) is resorted to very often. It is water-repellent penetrating to the subgrade through the joints, and at the same time it is easy to handle for additional lay-out modifications in the course of slab laying. Also, good results are given by the use of stone chips, asbestos waste and crushed slag. These materials can be utilized pure as well as treated with liquid bitumens. Roads intended for light traffic allow for the arrangement of an equalizer layer of regular untreated sand.

The evenness and regular outline of the equalizer level greatly influence the evenness and observance of transverse and longitudinal gradients on the surface of the precast pavement. Therefore while building roads of highest technical categories and roads in city streets for the purpose of levelling and compacting the equalizer layers (as well as the whole subgrade if it is made of sand), they utilize blade graders and compact machines travelling by rail. The rails are set strictly according to the grading elevations, which allows to attain a high precision of workmanship of the subgrade surface.

The progress of works involved in the arrangement of sand subgrades or sand equalizer levels consists of the following operations: sand haulage, its handling in-situ and coarse levelling by autograders or bulldozers; mounting of rails for blade graders to move; final leve-ling and compaction of the sand layer.

The rails are normally dismantled after the slabs are laid. During the course of slab laying they are utilized as control "signal towers" to check out the slab position and additionally level the surface of the sand course.

For the purpose of grading operations and simultaneous compaction of the sand layer (course) use may be made of self-propelled graders intended for the preparation of subgrades for cast-in-situ concrete pavements. Such machines are normally provided with grading blades and compact vibration bar. They can cope with the compaction of sand layers with a thickness of 20 to 30 cm. The equalizer layers of a small thickness can be compacted at one go of the machine. The compaction of sand untreated by any viscous substance is most effective with its optimal moisture content. Since the natural moisture content of sands is normally less than the optimal one, it is necessary to artificially moisten the sand layers by watering before compaction.

To move the blade graders use is often made of rail-forms which are also part of the mechanization set for the construction of cast-in-situ concrete pavements. The rail-forms should be mounted very thoroughly, since even minor distortions of their position in the transverse profile result in deformity of the pavement surface. The difference between the height of two adjacent links must not exceed 2 mm. The links of rail-forms are connected with one another with straps and bolts. To rule out lateral shears, the rail-forms are fixed in place by means of metal pins 0.6 to 0.8 m. long; they must be driven into the base through an orifice in the bottom plate. All the pins having been driven, and all the butts having been joined, for the purpose of setting the blade grader must make several runs on the rail-forms. After the running the position of the rail-forms is to be checked out by alignment, and the settings which are thus found must be rectified by way of padding the base material or setting-up the wooden pads. The rail-forms are mounted and dismantled with the aid of a special stacker or autocrane.

If no blade graders are available, use may be made of a simplified grader (23). The latter is used only to level the sand layer, shearing the sand excess and making storage for setting during compaction. The sand compaction is implemented by means of surface vibrators (e.g., C-414). The simplified grader moves along regular rails of wide gauge. They are mounted in a way similar to that of rail-forms.

There are various proposals regarding the improvement of sand subgrade preparation. According to the data by certain authors (23), as to levelling and compacting the sand subgrade, there are

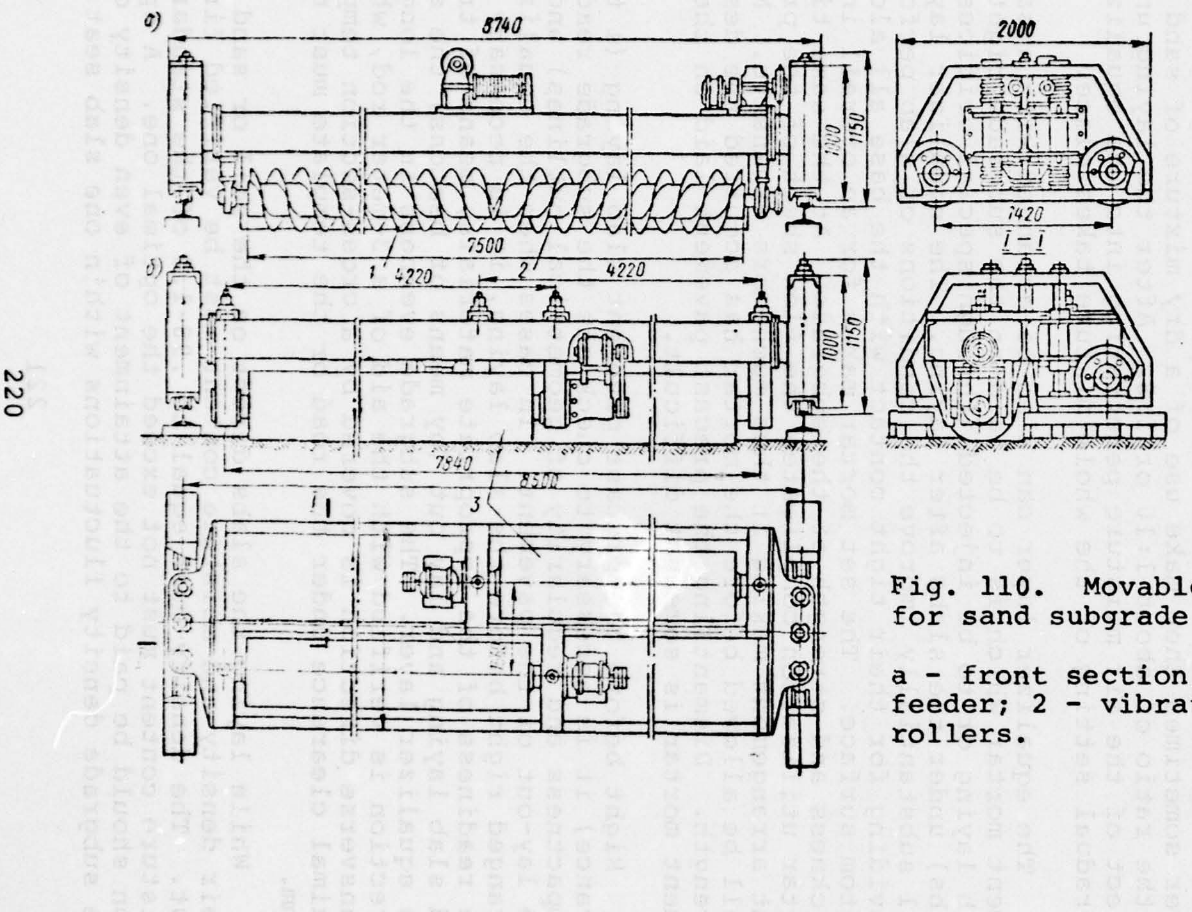


Fig. 110. Movable vibration rolling machine for sand subgrade finish.

a - front section; b - rear section; 1 - worm feeder; 2 - vibration plate; 3 - vibration rollers.

perspectives for the utilization of a set of machinery whose design is based on the principle of power vibration-rolled concrete (Fig. 110).

The machine moving along the rails consists of several sections. The front section represents a trolley with a worm feeder 1 and a vibration plate 2. The following sections have a system of vibration rollers 3, having devices for vertical movements within the frame which enable causing a growing pressure of vibration rollers on the base. The worm feeder, the vibration plate and the vibration rollers are provided with devices changing their position in the transverse profile and thus giving the sand subgrade or the equalizer layer the preset transverse gradients.

In case when the precast pavement is not supposed to be dismantled in the future, for the purpose of arranging the equalizer layer sometimes they make use of a dry mixture of sand and cement in the ratio of about 1:10 or 1:8. After the laying under the effect of the air moisture penetrating into the equalizer layer a gradual setting of the whole mixture takes place.

The equalizer layer can also be arranged with a sand and cement mortar which is to be laid on the subgrade right before the slab laying or to be injected (through special orifices in the slabs) under the slabs after laying. The equalizer layer of mortar will substantially improve the conditions of slab performance providing for their tight contact with the base all along the bottom surface. The set mortar makes for an overall increased thickness and strength of the subgrade. At the same time the mortar utilization complicates the flow sheet of the precast pavement arrangement making it thus much more expensive. No traffic shall be allowed before the mortar has acquired the design strength. Dismantling the precast pavement laid on the sand and cement mortar is somewhat difficult.

Right before the precast pavement slab laying (1 to 3 days in advance) it is necessary to check out the subgrade readiness (its compactness and regularity of geometrical outlines) and carry out the lay-out of the pavement. In cases when the equalizer layer is arranged right before the slab laying, it is necessary to verify the readiness of the appropriate materials, means of transportation and slab laying and lay out (by means of beacons) the surface of the equalizer layer. The subgrade evenness in the longitudinal direction is verified with the aid of a 3-meter rod, whereas the transverse direction is covered by a cross-section template. The maximal clearance under the road or the template must not exceed 5 mm.

While laying the slabs direct on the soil or sand subgrade, their density and moisture content must be verified first and foremost. The density must equal to .98-1.0 of the standard one, the moisture content must not exceed the optimal one. A special attention should be paid to the attainment of even density or compactness. The subgrade density fluctuations within one slab seat must not

exceed .01 to .02 gm/cm^3. If the subgrade density is uneven, it must be loosened to a depth of 8 to 10 cm, moistened to the optimal moisture content and once again compacted to attain the preset indeces.

The pavement layout is implemented by various means depending upon its design, type of slabs and proposed means of laying (Fig. 111). The simplest approach for carrying out the layout with rectangular slabs is to lay them without any pads. If it is provided to make a joint along the pavement axis, it may be limited to the layout of the pavement axis. If there will be no joint (e.g. - while laying hexagonal slabs), it is necessary to lay out any one edge of the pavement.

With the aid of a threadolite every 10-to-20 m strips of the axis (or the edge) are marked with wooden pickets and layout cord is fixed on to them tightly. The slabs are laid on the subgrade on the right and the left sides of the cord very close to it. While laying out the edge, the slab laying is done only on the one side of the cord. For the purpose of track pavement laying, on the prepared subgrade inside edges of the track are marked with the aid of pickets and cord. In the course of slab laying on the butt pads the pad positions are also fixed by way of cords (see Fig. 111, c).

In most cases the construction sites of precast pavements confine themselves only to layout in plane. The vertical elevations are verified during the progress of slab laying by the alignment sight and rack and level. But sometimes, to attain high precision, high-level beacons are placed on the vertical elevations. Such beacons may be

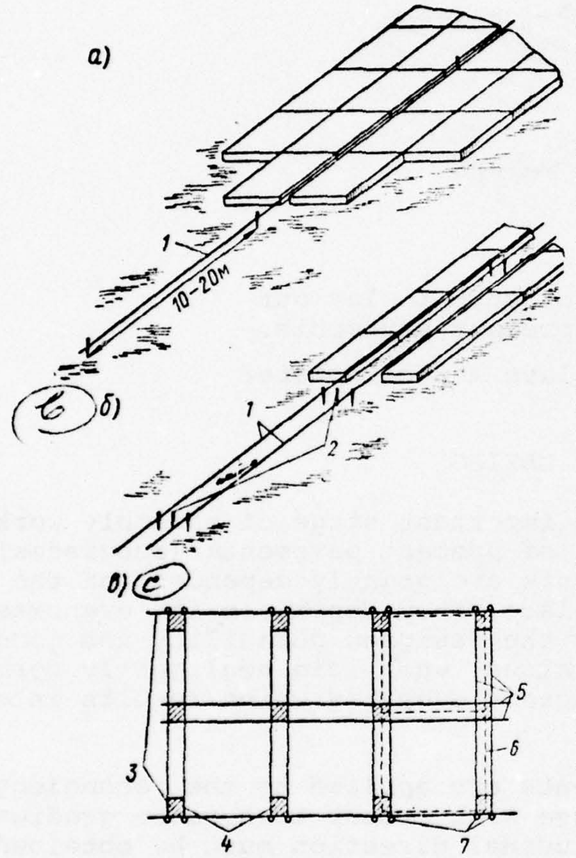


Fig. 111. Chart of Precast Pavement Layout:

a - solid; b - track;
c - solid on butt pads;
1 - layout cords; 2 - axis picket;
3 - layout lateral cords; 4 - butt pads; 5 - auxiliary layout cords (to be removed after pad laying);
6 - slab outline; 7 - layout pickets.

rails utilized for moving the machinery grading the subgrade. Another variant of the elevation layout consists in setting up a rib-plank enclosure on the road shoulders parallel to the outer edges. The upper surface of the planks is set up by alignment sight so as to make it correspond to the design elevations of the roadway curb. The slab position is verified by the template and clinometer (Fig. 112). The bottom edge of the template must have an alignment equal to that of the precast pavement surface alignment.

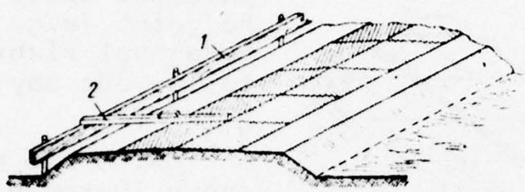


Fig. 112. Rib-plank enclosure to lay out vertical elevations of precast pavements.

1 - enclosure; 2 - template and clinometer

25. SLAB LAYING

Slab laying on the bed is an important stage of assembly works during the course of construction of precast pavements (subgrades). Quality indices of precast pavements are greatly dependent on the quality of laying, in the first place, they depend on its evenness and durability. The slabs having the designed durability and good geometrical form (precise design sizes) when laid negligently form a precast pavement with unsatisfactory evenness which results into its untimely destruction.

The following main requirements are applied to the technology of slab laying: a pavement surface with preset transverse gradients and required evenness in a longitudinal direction must be obtained as a result of laying. Each precast pavement slab must be tightly placed along all its lower surface on the bed. The correct position of butting units of adjoining slabs and the design width of joints between them must be ensured in the course of laying.

The choice of the machinery for slab laying depends on the above requirements for the quality of construction and the productivity of the machinery. The productivity must be sufficient enough to secure the design flow speed in fixing the precast pavement. In the majority of cases slab laying is done with the help of self-propelled cranes designed for handling. The choice of the cranes is done according to their productivity and the boom of the crane. The load-lifting capacity of the crane must correspond to the weight of a slab with a certain margin (20-40%) for beating of cohesive

forces arising between the slabs and the groove or between the slabs and the soil while kept in storage for a long time, on the road shoulder, etc.

It must be taken into account that the load-lifting capacity of the cranes is indicated with the minimal jib boom. With increasing the jib boom the load-lifting capacity of the cranes is sharply decreased (2-5 times less). Slab laying with the minimal jib boom, as a rule, is inexpedient. The more is the jib boom, the more slabs it is possible to put with the crane from one spot and the higher is its productivity. When laying big-sized slabs it is desirable to utilize the cranes with the working jib boom of no less than 7-10 m. Therefore when selecting the cranes it is recommendable to check up their load-lifting capacity with the maximal (and not the minimal) jib boom. The technical performance of some automobile cranes is given in Table 36.

TABLE 36

Model & Type of the Crane	Crane Weight in Tons	Maximal Load-Lifting Capacity		Minimal Load-Lifting Capacity	
		T	With the jib boom in metres	T	With the maximal jib boom in metres
AK-5, mechanical full-swing, chassied ЗIL-164	8.3	5	2.5	1	5.5
AK-5g, ditto	8.3	5	2.5	1	5.5
K-51, mechanical full-swing, chassied MAЗ-200	12.15	5	3.8	2.	6.5
K-52, diesel-electric, full-swing, chassied MAЗ-200	13	5	3.8	2	6.5
SMK-7, ditto	--	7.5	4	2	8.5
MKA-10, hydraulic full-swing chassied MAЗ-200	14	10	4	2.2	10
K-104, diesel-electric full-swing, chassied KrAЗ-219	22.8	10	4	2.2	10
K-162, diesel-electric full-swing, chassied YaAЗ-219	20.8	15	4	3.25	10

If the load-lifting capacity of the crane with the maximal jib boom is insufficient, then it can be taken for the limit working jib boom a certain average position of the jib. However, such a position must be strictly determined with the help of special stopping devices so that the crane operator may not exceed the set limit and work with a big (dangerous) jib boom.

The maneuverability of the cranes is also of great importance for the productivity. In the course of slab laying or slab

unloading it is necessary to change crane locations often. The cranes that can be quickly moved from one location to another should be preferred and do not require additional movable supports raising their stability when under load.

The best cranes for the purpose fulfilling the above requirement are excavator crawler cranes. These cranes have a considerable dead weight and a good stability due to a big support surface. At the same time these cranes have drawbacks as well. Metal caterpillar tracks destroy the slabs and therefore excavator-cranes in the majority of cases are installed outside the thoroughfare on road shoulders or on the dividing strip. As a result the distance between the crane and the extreme longitudinal row of slabs increases and consequently it is necessary to increase the jib boom.

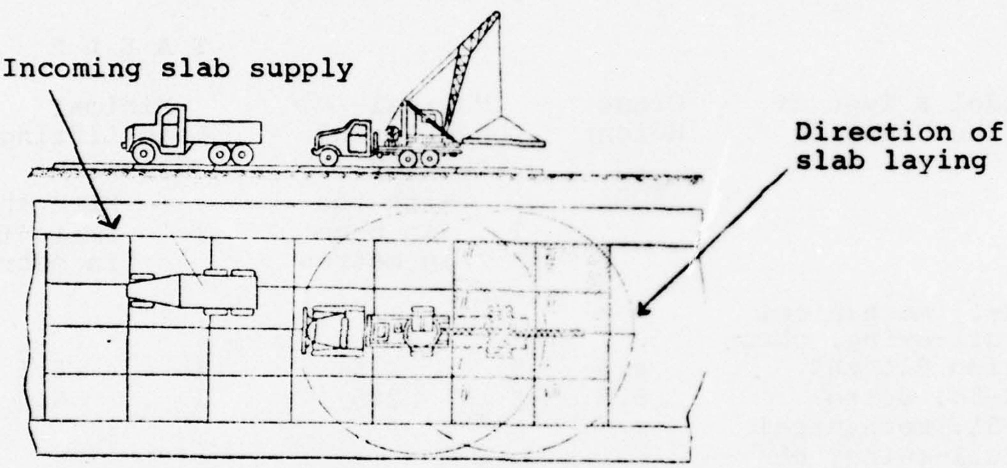


Fig. 113. Technological chart of slab laying by means of an autocrane from a truck.

Besides crawler cranes are not designed for self-propelled movement. It is necessary to load them on trailers even for moving at comparatively short distances (several kilometres). Because of these factors crawler cranes are not widely used for precast pavement laying. Autocranes during the course of slab laying are usually placed on the already laid part of the precast pavement.

The slabs are taken by the cranes from the trucks of other vehicles, or from the stacks situated on road shoulders and they are put on the subgrade in front. The technological chart of slab laying on the subgrade by means of an autocrane from a truck is represented by Fig. 113. The Roman numerals (I, II, III, IV, V, VI, VII, VIII) indicate the order of slab laying.

Firstly the slabs adjoining the axis of the pavement are laid and the others follow after. Having laid one full transverse row the crane moves forward on just laid slabs. The checking up of

the quality of laying is being done at the same time. The well-laid slabs must not sway or noticeably sag under the crane. The technological chart of slab laying from the stacks on road shoulders by means of a self-propelled crane of a considerable load-lifting capacity and with a lengthened jib is represented by Fig. 114. Due to this the cranes from one location lays three transverse rows of slabs.

Special assembly loops are usually provided for in the slab design. Four of them are provided in the majority of cases. The loop placement must be checked up with calculation so that inademissable stresses do not arise when the slabs are lifted.

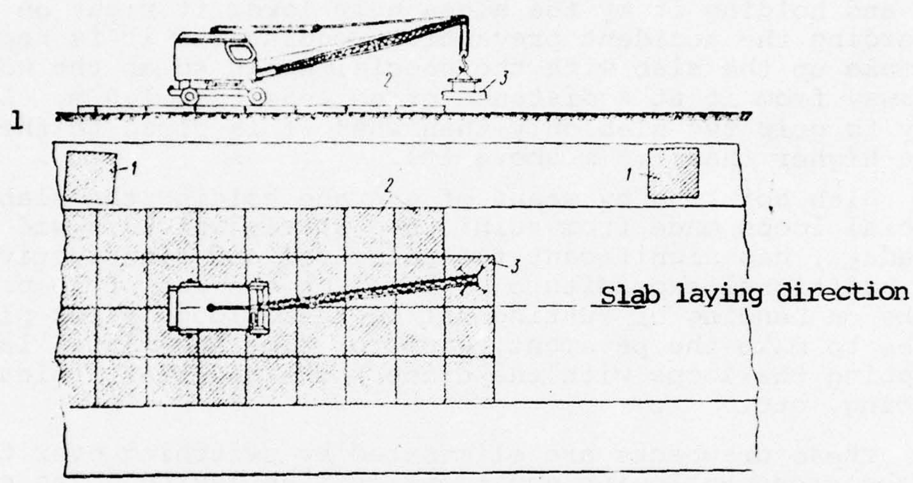


Fig. 114. Technological chart of slab laying from stacks on road shoulders by means of a self-propelled crane with a lengthened jib:

1 - slab stacks on road shoulders; 2 - laid slabs; 3 - slab at the moment of laying.

Each slab must be lowered precisely at a designed spot so that the slab touch with its lower surface the subgrade. A tight contact must be ensured at any point of the slab lower surface and the subgrade. If this is not the case the rated operating conditions of the slab performance under load are disrupted. Additional stresses will arise in the slab which under unfavourable conditions may considerably exceed the rated operating conditions and cause the slab damage.

Displacements of slabs in plane increase the joint dimensions and disrupt the design construction of slab joining. Also the horizontal movements along the subgrade after joining are hard to implement without special equipment. Besides, when slabs are moved horizontally along the subgrade the evenness of the latter is disrupted. The slab misalignments when lowering are inadmissible as they may cause the subgrade damage.

To raise the quality of laying the cranes are supplied with special gripping devices by means of which a horizontal position of the slab is assured at the moment of its lowering on to the subgrade. The most common design of such a device is a tetragonal crosspiece with hooks on the cords (or chains) in the corners. The crosspiece is suspended to the hoisting steel line of the crane on to the centrally-positioned stirrup. When the geometrical slab dimensions are accurately observed such a suspension support ensures a horizontal position of the raised slab in the air. However it is not possible to completely avoid misalignments as there are some errors in the slab dimensions and the placement of loops on them. Therefore to help the crane operator one to two workmen are assigned to him. They take up the slab at the moment of its lowering and holding it by the edges help lower it right on the spot. According the accident prevention regulations it is recommendable to take up the slab with the special hooks so as the workmen must be away from it at a distance of no less than 1.0 m. It is necessary to grip the slab only then when it is close to the subgrade (not higher than 0.5 m above it).

Slab hoisting by means of a crane holding the slabs with the special loops made from reinforced steel, which is widely used nowadays, has significant technological and constructive drawbacks: the additional expenditure of metal on the use of loops, additional works on bending or cutting off of these loops after placing the slabs to make the pavement, waste of time and manual labour on tripping the loops with the crane hooks and their release after placing, etc.

These drawbacks are eliminated by switching over to the use of the vacuum-gripping equipment in slab laying. Its essence is as follows: the slab is pressed against the vacuum-chamber by rarefying created in the chamber by the special pumps. The vacuum-chamber is hoisted to the crane jib that lifts it and carries it together with the slab "pressed" against it. The chart of the experimental slab vacuum-layer is shown in Fig. 115 (37).

The first pilot specimen of the vacuum-gripping equipment designed for laying big slabs with an area of 12 m^2 and a weight up to 4.5 t was created at the All-Union Road Research Institute in 1963. The equipment of such type is also available abroad.

The main advantage of such a device is the speed of gripping and releasing of the slab (within several seconds) without additional manual labour. Vacuum-gripping devices may be utilized not only in slab laying but in speeding up all operations on slab handling. According to the data of the candidate of sciences A. A. Timofeev when vacuum-gripping devices are utilized effectively, then due to the labour productivity increase, the cost of slab laying can be reduced 2/2.5 times. The accident prevention requirements (in the first place the removal of workmen from the area of possible slab drops) while operating the vacuum-gripping

device must be enforced even more strictly than in operating the usual equipment.

The subgrades prepared for precast pavement laying, even after a most thorough alignment, have certain micro-unevenness. Therefore after the first laying go there is no assurance that the slab will rest sufficiently tightly on the subgrade. There is a means to verify the tightness of the slab rest, which is as follows: The slab is laid in place while the hoisting steel line is being temporarily loosened or the vacuum gripping device is being disconnected which makes the slab weight rest fully on the subgrade. In 20 to 30 sec. the slab is again hoisted in the air and, judging by the slab imprint on the subgrade, it is possible to assess the tightness of the slab rest on it.

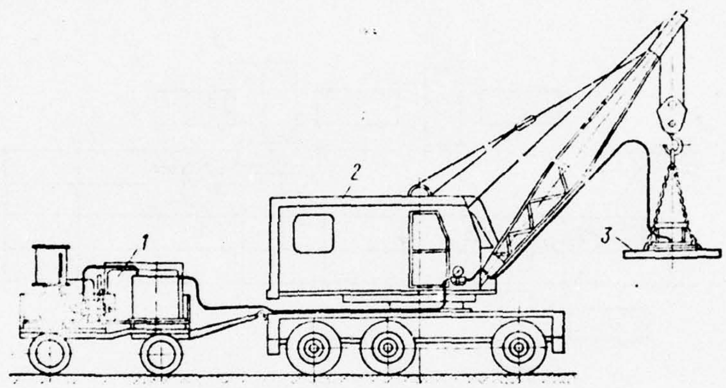


Fig. 115. Chart: experimental vacuum slab layer:

1 - trolley and vacuum pump; 2 - crane and vacuum gripping device; 3 - slab

If necessary, the subgrade is aligned by means of grading off the individual small bumps or by partial filling up the lower spots, during this time the slab being suspended aside on the pull steel line of the crane at a distance of 3 to 4 m. Provision must be made to absolutely ban any work under the slab suspended by the crane steel line. The subgrade having been aligned, the slab laying process is repeated; that is the slab is placed again on the subgrade. If no additional measures are taken to improve the contact between the slab and the subgrade (e.g. - vibration), the quality of slab rest on the subgrade is verified again. Sometimes the up-and-down operation for the big-sized slabs is to be repeated 3 to 4 times.

Simultaneously with the verification of the slab-to-subgrade rest tightness the pavement smoothness is also checked out. For this purpose a 3-meter rack is placed on the pavement so as to cover the previously placed slabs, as well as a new one, not yet released from the gripping device. During this operation the clearance in any point under the rack must not exceed 2 mm, i.e. as to the evenness, the precast pavement must meet the standards

set for regular cast-in-situ ones. It should be kept in mind, however, that these measurements cannot always be considered the final characteristics of the evenness. In most cases as certain slab setting occurs under the influence of traffic during the first period of the pavement service. Thus the evenness of the latter is recommended to be verified once again in 10 to 15 days after its opening to traffic. Besides, for preliminary verification of the pavement smoothness during the progress of slab laying it is recommended to use not a 3-meter rack but a 4-meter control one.

Slab laying by crane is characterized by a considerable time consumption to handle one slab. Actually the productivity of jib cranes fluctuates from 5 to 10 (rarely 15 to 18) slabs per hour.

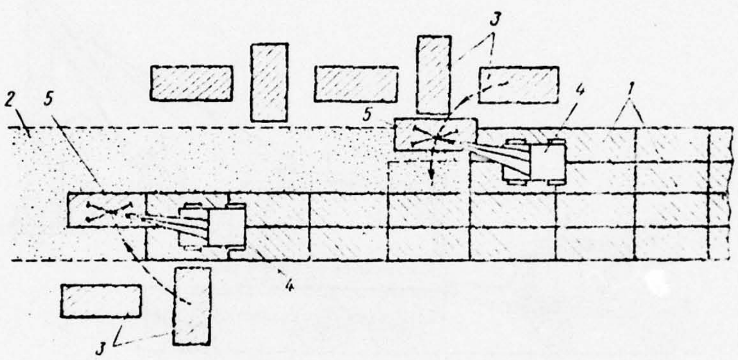


Fig. 116. Slab laying by two cranes in one flow:

1 - slabs laid; 2 - prepared subgrade; 3 - slabs preliminary placed on the road shoulder; 4 - cranes laying slabs; 5 - slabs at the moment of laying.

During this operation the greater part of the work time is spent on check hoists, check subgrade alignment, evenness checks etc. As to the vacuum-gripping device, its utilization has considerably cut down the time necessary for gripping and releasing the slabs. However, the time necessary for carrying out other operations remains unchanged. The productivity of cranes engaged in the arrangement of precast pavements of temporary type with lower standards as to their evenness and slab-to-subgrade rest tightness is about 2 to 3 times higher than the one during the arrangement of precast pavements of permanent type. The utilization of big-sized slabs makes it possible to increase the flow speed on the pavement arrangement, regardless of the fact that the time consumption for the laying of one slab somewhat increases. The low productivity of the slab laying is the reason why one jib crane cannot always ensure the necessary flow speed on the arrangement of precast pavement. In such it is possible to utilize two cranes simultaneously during one slab-laying flow. An example of such a flow sheet is shown by Fig. 116.

Each crane lays the slabs on one half of the travelled part. In order to guarantee their maximum productiveness, the slabs are brought beforehand to the place of laying and laid out on the shoulders of the road. The scheme of their disposition depends on the width of the road shoulder, the dimensions of the slabs and the length of the crane derrick. Fig. 116 shows the disposition of the slabs in two stacks opposite each cross sectional row of the pavement. In this case, a turn of the crane derrick does not exceed 90° which shortens the time expended on one cycle of its work.

Cranes with large lifting capacity and with long derricks can carry out the laying of two to three rows of slabs with one position. Correspondingly, it is possible to arrange the piles (consisting of four-six slabs) in one or two transverse rows. In this case, the time in transporting the slabs from the pile to the base is increased, but the total time in shifting the position of the crane is greatly reduced.

In some designs of rigid prefabricated pavements, provision is made for laying the slabs on foundations in the form of slabs, cross ties and longitudinal foundations, which are set up at angles to the slabs in the zone of the junction or along its contour. Moreover, it is customary ti reduce the number of repeated liftings of the slab, but the volume of work in preparing the base is increased.

In the majority of cases, installation of the linings is done manually. In planning and packing the base with shovels, recesses are made in which the linings are installed. In some cases, slightly mechanized means are used for this (for example, a special tractor-mounted piece of equipment with an easily maneuverable tractor of the "Belarus" type). The equipment must have a digging instrument, which at once would dig out the depression of the required dimensions in the base, and the boom with a small lifting capacity having a grab bucket suitable for lifting and transporting the lining without installing special reinforcing devices thereon.

When installing, the reference marks above the lining must be matched with the reference marks of the pavement slab surface. The accuracy of installing the linings is checked with a level. Checking the position of the lining by means of a level can be done only on stakes and discontinuities of the longitudinal profile, and all the intermediate indicators are established according to surveyor's range poles.

In addition to accurately observing the vertical control points of the lining center, it is also necessary to strive for a correct position of the entire surface. It must be strictly parallel to the pavement surface. On the horizontal parts of the road, the lining surfaces must have only the planned transverse inclination, and this applies both for longitudinal and transverse direction. The correctness of laying the linings in this regard is checked with a wooden measuring rod having a length of 4-5 m, laying it simultaneously on 3-4 linings. There must be no gaps between the measuring rod and the surface of the lining, since subsequently these may lead to

shearing of the concrete on the slab edges. As a rule, one is not successful in correctly laying the lining at once, thus the entire process is repeated 2-3 times.

In the majority of cases, the slabs of prefabricated pavements are not supported along the contour or at individual points (on the lining), but the entire lower surface is considered supported on an elastic semi-area. Consequently, the base between the linings must be carefully packed down and levelled flush with them. Frequent laying of the linings makes it possible to do this rather accurately, thanks to which the working efficiency of the cranes is greatly increased, however, the labor expended in laying the slabs is so great that in the long run the former does not compensate for the latter.

Imperfection in laying the slabs with boom cranes is especially perceptible on pavements of the main type, intended for intense automobile traffic at high speeds.

The evenness of prefabricated pavements constructed according to described technology is usually lower than the evenness of corresponding monolithic pavements. The stability of the slabs under the movement of heavy automobiles is insufficient. At such speeds, the stability of such pavements is not high.

The effort to do away with these shortcomings brought about the necessity of working out a series of proposals for improving the technological process. The purpose of the majority of these is to improve the contact of the slabs with the base, while at the same time increasing the evenness of the pavement. One of these proposals provides for constructing a thin (1-3 cm) evening layer made of a plastic cement-sand solution on the surface of the base. It is recommended to use solutions made of coarse grained or medium grained sand, with a cement content of the order to 250-300 kg/m^3 and settling of the cone of 3-5 cm.

The slabs are laid down on the solution until it sets. Then a light roller is run over it or the transfer surface of a vibrator is used. Thanks to the high degree of deformation of the plastic solution (within wide limits) it is possible to change the position of the slabs according to height and to regulate the evenness of the pavement surface. Tight contact between the slabs and the base is guaranteed after hardening of the solution.

Injection ofhthe solution can also be used in the construction of prefabricated pavements made of medium and heavy slabs. For this purpose, it is customary to use slabe with a curvilinear lower surface (resembling a flat cupola or four-ramp roof with small inclinations).

The slabs are laid on the base with boom or gantry cranes and then lightly pressed down with a roller, obtaining the required evenness of the pavement surface. Then, the solution which fills the space between the lower surface of the slab and the base (Fig. 117) is injected with solution pumps through the apertures in the slabs (there may be one or several) under a pressure of 1-2 atm.

It is possible to inject the solution under slabs with a rectilinear lower surface, laid along the contour or along the corners on special linings such that a small (1-3 cm) clearance remains between the lower surface of the slabs and the base.

It is desirable to inject the solution under the slabs in the presence of compact bases (crushed stone, from reinforced ground).

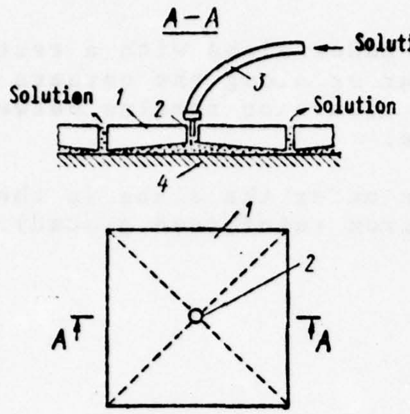


Fig. 117.--Injection of the solution under the slabs of prefabricated pavements: 1-slab with a roof-shaped lower surface; 2-aperture for injecting the solution; 3-solution pump hose; 4-Base

In this case it is not necessary to even out the layer made of fine-grained, loose materials. Water-cement solutions with compositions from 1:0.5 up to 1:3 and cement-sand mixtures with compositions of 1:1:0.72 (cement, sand, water) [37] are used for the injecting. Up to 2-3 wt.% cement $CaCl_2$ or NaCl are introduced into the solution to hasten the hardening and to reduce the freezing temperature, especially in the case of low air temperatures. Portland cement of brand 300 and higher are used as astringent.

The solutions for injection are prepared in solution mixers near the place of work or are conveyed by automobile from the concrete plants. Injection is accomplished with the aid of solution pumps with an exemplary efficiency of 0.5-1.0 m3/h. In some slab constructions, metal nozzles are made in the aperture with a thread into which the metal tip of the solution pump hose is screwed. In other designs, the hose for feeding the solution is let directly into the slab aperture or into a narrow metal funnel inserted into the aperture. The injection is stopped with the appearance of the solution into the junctions between the slabs or in specially made apertures of small diameter (5-10 mm) near the slab edges. After conclusion of the process, all the apertures are stopped up with concrete plugs on the solution or simply with the solution.

Traffic on the pavement may not be opened before 1-2 days in warm weather or 3-4 days with an average air temperature of 10-15°. In connectin with this, it is not permitted to use a recently laid pavement for transporting the slabs to the place where they are to be laid. The cranes must not be positioned outside of the travelled part. In particular, with this method it is possible to use crane gantries moving along rails laid on the shoulders (Fig. 118). It is not recommended to carry out the injection at negative air temperatures.

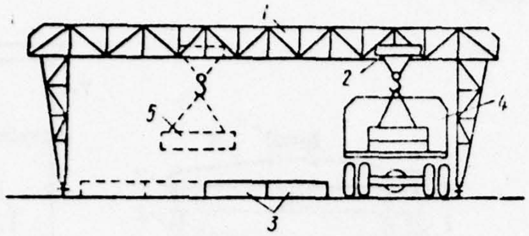


Fig. 118.--Scheme for laying the slabs with a gantry crane: 1-gantry crane; 2-hoist; 3-laid slabs; 4-automobile with slabs; 5-slab, moved by a hoist in transverse direction to the place of laying.

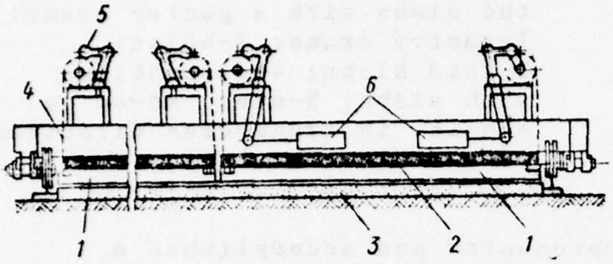
In 1955, Prof. V.M. Mogilevich presented and accomplished a principally new technology for constructing prefabricated pavements in the experimental sector. Its essence included changing the sequence of installing the pavement and the base. Initially, with the aid of special equipment, the rigid slabs of the prefabricated pavement were suspended accutately in the air in planned position. The surface of the slabs corresponded to the planned vertical reference marks to the given longitudinal and transverse inclinations. Then, then a thin base layer made of finely dispersed materials was placed under the slabs. With such a method it was not possible to make any requirements as to evenness of the base.

The material of the base under the slabs which are suspended in the air could be prepared and simultaneously packed down by different methods: blowing compressed air from compressors or with low pressure ventilators; washing up with water; using mechanized means with the aid of different pushers, vibrators and sand slingers.

The first method was tried in practice. The used equipment consisted of two machines: a slab-laying and a blowing machine,* and the entire process was carried out as follows. The slab-laying machine, mounted on a metal four-wheel frame, was moved along rails. A compressor was installed on the frame feeding a system of pneumatic cylinders which, with the aid of chain-clamps lift the pavement slabs and clamp them at the bottom to a rack-and-pinion lock. With the aid of a system of screws, the clamps are installed so that the geometrical plane tangent to their lower grain precisely corresponds to the planned contour of the pavement. The slabs, pressed with their upper plane to the clamps, occupy the planned position and form a pavement with a smooth surface without any recesses on the slab junctions (Fig. 119).

The blower machine consists of a bin for sand, a drum feeder with a sand-conveying nozzle and a ventilator for forcing the air. After the slab is set in the air in the planned position with the aid of the slab-laying machine, the blower machine forces sand into the gap between the slab and the lower layer of the base (Fig. 120).

*The machine was worked out and manufactured by a group of engineers: V.M. Mogilevich, D.I. Zazhirei, S.S. Semenov, G.P. Korotkov, A.P. Mishchenko, A.D. Mixailov, T.A. Zozluleu.



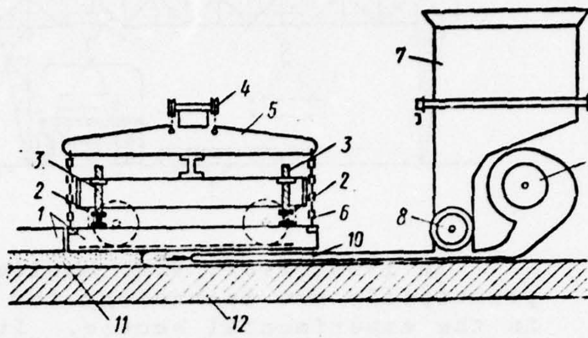


Fig. 119.--Drawing of a slab-laying machine: 1-Slabs lifted in planned position; 2-rack and pinion lock; 3-lower layer of the base; 4-clamp chain for suspending the slabs; 5-slab lifting mechanism; 6-Pneumatic cylinder for lifting the slabs.

Fig. 120--Scheme for forcing the sand under the slabs with the aid of compressed air:
1-Slabs; 2-Rack and pinion lock; 3-Screws for regulating the rack and pinion lock; 4-lifting mechanism; 5-Balancer; 6-Clamp chain; 7-Sand bin; 8-dosing apparatus (drum feeder); 9-Fan; 10-Nozzle; 11-upper (blown) layer of the sand base; 12-lower layer of the base

As the experimental works showed, the use of this technology provides the required smoothness of the prefabricated pavement, good contact with the base and a high degree of density of its upper layer. However, the efficiency of the experimental machine was low and its design required considerable improvement. In particular, vacuum clamps should be used instead of chain clamps, which greatly speeds up the operations of lifting and lowering the slabs.

Tight contact of the pavement with the base is obtained by vibrating (vibration-setting) of the slabs after they are laid. The essence of this method includes the fact that an oscillating movement of low amplitude is communicated to the dispersed base material, but with a high frequency. As a result of the vibration, we obtain redistribution of the base material directly under the slab and filling of the empty spaces.

The redistribution of the plastic materials takes place very effectively under the effect of vibration: the unhardened cement-ground mixtures or the cement solutions. The contact of the slabs with the layers of air-dry dispersion materials is also improved (sands, dry cement mixtures). Under the effect of the vibration, the sands partially take on the properties of a liquid and spread out under the slab. Vibration of the sandy materials having optimum humidity give better results. With vibration, extremely dry, fine or over-moist sands sometimes are ejected through the junctions between the slabs.

At the present time, the vibration method has still been insufficiently worked out. The questions of determining the necessary frequency and amplitude of vibrations, the required power of the vibrators and other characteristics depending on the dimensions and the weight of the slab, and also on the qualitative material of the base, are solved basically by experimentation. For this purpose, after vibration, control liftings of the slabs are carried out and it is visually (according to the imprint of the base) determined how long vibration with the given vibrator should be carried out to guarantee full contact between the slab and the base. In order to provide a tight setting of the slabs on the base, the value of the perturbing vibrator forces must be for example 1.5 times higher than the weight of the slab and of the vibrator machine [37].

Some variations of the vibrating machines used for these purposes have been worked out. One of these is the self-propelled vibro-setting machine AM-66 with a productivity of 1800-2200 m^2 of the prefabricated pavement for a working shift. It is an automotive semi-trailer on which 10 vibrators are mounted having a vibrating frequencies of 1700, 1275 and 875 per minute. The maximum support surface of the vehicle is 1840 x 5000 mm. For the vibrations, the machine is set up on each slab individually (fig. 121). The length of time of the vibration amounts on the average to 25-50 sec. The vibrators are lifted up before moving the machine. The machine is transported on an automobile tractor MAZ-200V.

With the aid of the AM-66 vehicle, it is possible to provide a good quality of vibration setting of slabs with a weight up to 4.2 t. With a low weight of the slabs, it is possible to reduce the vibration time or to shut off part of the vibrators.

After laying the slabs, in case of necessity, repeated vibration of the slabs is carried out to even out the level of the pavement. With this machine, vibrators are set up on the junctions in which one slabs stand (more than 2-3 mm) higher than the others.

From the number of other machines it is necessary to note the V-1 vibrator, developed by workers of the Kiev automobile road institute. After setting up the framework of the vibrator on the slab, it is firmly fastened to the mounting eyelet. The positive aspect of this mechanism is the possibility of changing its working regime [12] within wide limits. The rotational speed of the shaft is 920-2200 rpm. Interchangeable gears areffixed to the drive shaft and to the driven shaft of the vibrator. Five sets of them make it

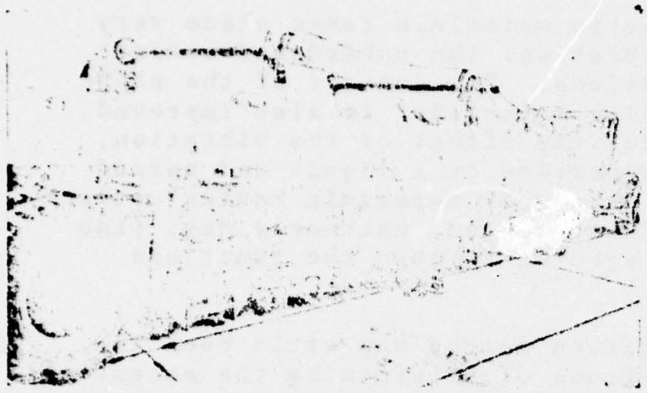


Fig. 121.--Vibrating machine AM-66 (vibrators lowered onto the slab).

possible to obtain nine different vibration frequencies. By exchanging the debalancers, it is possible to change the perturbation force of the fibrator from 670-4870 kg. Thus regulating the basic parameters of the vibrator we select the optimum working regime for slabs of different weight, laying on different bases. The weight of the vibrator V-1 with the frame is 430 kg. The output under average conditions is up to 800 m^2 of prefabricated slabs per shift.

It is recommended to use the vibration laver and leveling with vibrations when laying slabs on plastic, freshly-laid cement solution or on cement-ground mixtures, sand base with an optimum moisture and with a thickness of not less than 15 cm. Vibrating is not effective whenllaying slabs on a solid base with a thin leveling layer made of dry dispersion materials. Moreover, the great efficiency of this process (especially on a solid base), may cause the appearance of hardly noticeable cracks in the slabs, which subsequently may lead to premature destruction of the pavement.

The selection of this or any technology of laying slabs is determined by the designation of the road, the design of the slabs, the presence of equipment, the season when the work is being carried out and other special features of each concrete constructional object. For maximum use of the advantages of prefabricated pavements, their installation must be carried out according to the technology which would guarantee the possibility of opening traffic at once after laying of the slabs. For this purpose, an effort is made to avoid work involving the use of cement solutions or concrete mixtures, hardening after laying, since this creates lags in opening the traffic, worsens the condition for dismantling the pavement (in case of necessity) and the repeated use of the slabs. At the same time, the eveness, the tightness of support on the base and the working life of the pavement laid on a solution is higher. Thus, it is recommended to use the given method on roads with intense and heavy traffic in those cases where immediate opening to traffic is not required and dismantling of the pavement is not presumed with repeated use of the slabs.

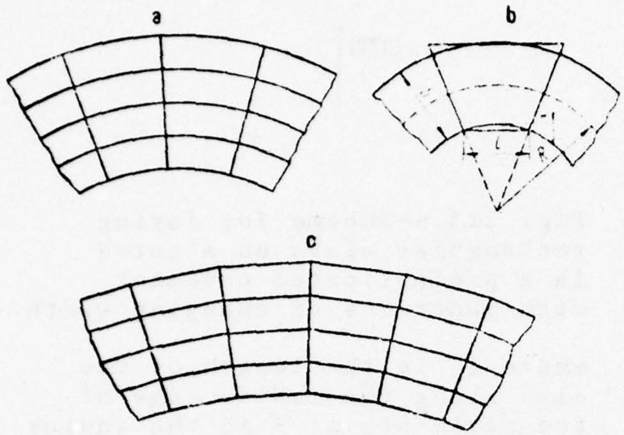


Fig. 122.--Scheme for laying the prefabricated pavements on curves: a-from slabs with two curvilinear grains; b-scheme for determining the necessary widening of the pavement from trapezoidal slabs; c-from slabs with a trapezoidal shape.

Laying slabs on curvilinear parts is more domplicated than on rectilinear parts, since rectangular and hexagonal slabs of standard shape (especially ones of large dimension) cannot be inserted into the curvilinear contour of the travelled part. The possible different variations for installing prefabricated pavements on curves: 1) special slabs are made for this, the shape of which is determined by the contour of the travelled part on the curve; 2) standard rectangular (or hexagonal) slabs are used for laying, providing curvilinearity of the travelled part due to a changed width of the junctions; 3) from the standard slabs, pavements are installed with broken edges, but with an increase of width, in the limits of which the planned travelled part is inserted.

The production of slabs with a special shape, changing depending on the radius of the curve, guarantees the quality of the prefabricated pavement to the highest degree. For curvilinear sections with a small radius of curvature, they make slabs having two curvilinear grains, for parts with relatively large radii, they make slabs of trapezoidal form (Fig. 122). With the use of such slabs, the width of the pavement must be greater than planned in order that the curvlinear travelled part may by inserted into the laid prefabricated pavement with broken edges. The value of the widening can be determined approximately according to the following fofmula:

$$X = \frac{l^2}{8\left(R - \frac{b}{2}\right)}, \qquad (172)$$

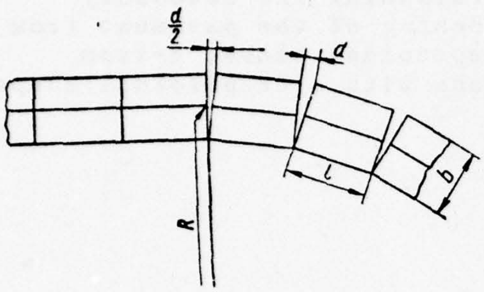


Fig. 123.--Scheme for laying rectangular slabs on a curve in a prefabricated pavement with junctions of changing width.

where l is the length of the slab along the inside edge of the pavement, m; R is the radius of the curve (along the axis of the travelled part), m; b-is the width of the travelled part, m.

Usually, the value of this widening is not great. So, with a length of the slabs of 5 m, a width of the travelled part of 7.5 m and a radius of the curve of 100 m, it amounts to about 3 cm.

The value of the widening increases with a decrease of the radius and with an increase of the slab length. It must be taken into account when manufacturing the slabs, suitably increasing their width.

The installation of prefabricaged pavements on curves of specially manufactured slabs with a non-standardized form together with the positive sides has essentialyshortcomings. Each disruption of a uniform outlet with mass standard production unavoidably involves a reduction in plant-manufacturing productivity and makes it production more costly. The need for non-standard forms changing as a function of the curves is increasing. Thus recourse is taken to manufacturing special slabs relatively seldom.

Standard slabs are used much more frequently, using the methods described below for laying them, or the ones in general discarded from prefabricated designs and monolithic pavements are set up in the limits of the curvilinear parts.

On the curves of large radii it is possible to lay pavements from standard rectangular (or hexagonal) slabs moreover providing a curvilinear contour of the passing part due to the changing width of the transverse junctions (Fig. 123). The junctions have a minimum width (1-2 mm) along the inside edge of the travelled part and a maximum width along the inside. The increase in the width of the junction (opening of the junction) is greater the wider the passing part and the longer the laid slabs. Theopening of the slab decreases with an increase in the curve radius.

The value of the junction opening d can be determined with an accuracy sufficient for practical purposes according to the formula

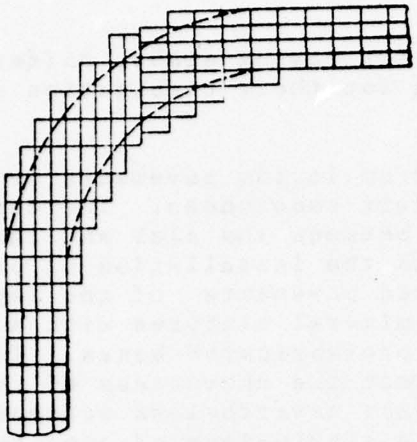


Fig. 124.--Scheme for laying a prefabricated pavement of rectangular slabs on a curve of small radius.

$$d = \frac{bl}{R - \frac{b}{2}}, \qquad (173)$$

where b is the width of the passing part, m; l is the length of the slab;m; R is the radius of the curve, m.

An excessive opening of the junctions must not be permitted, since wide junctions usually lower the smoothness of the pavement and worsen the conditions of traffic movement. These shortcomings are especially perceived on a traffic land adjoining the outside edge of the passing part where the width of the wedge-shaped junction is maximum.

The limit permissible opening of the junction is determined in each particular case, moreover, the technical category of the road, the character of the traffic, the methods of filling the junctions, etc. are taken into account. In the majority of cases, installation of junctions wider than 25-30 mm must not be permitted. Such a limitation is fully possible with the curve radii used at the present time. So, with a width of the travelled part of 7.5 mm, the slab length 4 m and the curve radius 1500 m, the additional opening of the junction will be equal to a total of 20 mm.

When installing prefabricated bases, it is possible to increase the permitted opening of the junctions, taking into account that they will be covered with a layer of pavement. In all cases (in pavements and in bases), widened junctions must be filled with material reliably protecting them from obstruction and the penetration of water.

On curves of small radii with turning angles equal to 90°, laying of the prefabricated pavement with rectangular slabs can be carried out according to the drawing shown in Fig. 124.

The curvilinear passing part it fitted into the limits of the laid pavement, thanks to a certain (although irregular) increase of its width. For the convenience of drivers, the limits of the passing part must be clearly marked with colored lines. The advantage of the given laying scheme is the use of ordinary standard slabs. The disadvantage is somewhat of an overexpenditure of the slabs and (irregular (with indentations) overlapping of a part of the shoulder with slabs. At turning angles not equal to 90°, such a scheme is not accomplished in a pure form. It is necessary to lay one-two rows in the middle part of the curve made of irregularly shaped slabs or to fix a small part of it with monolithic concrete.

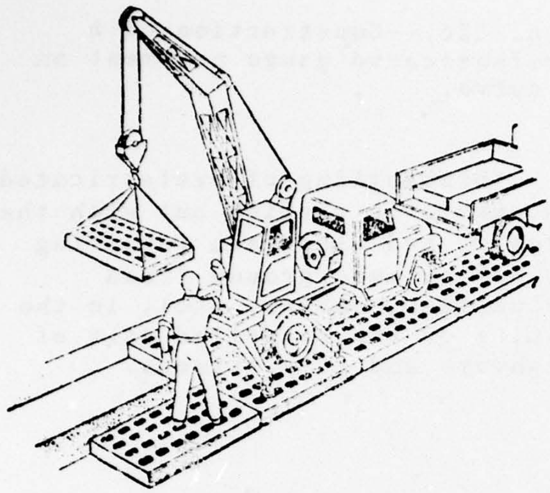
In addition to the examined schemes for laying slabs, different variations can also be realized providing for their combination on a section of one curve.

Laying prefabricated bases differs from laying pavements by some reduction in the requirements for their smoothness. The conditions for observing tightness of contact between the slab and the lower-lying layer are maintained also with the installation of prefabricated pavements. Two or three layered pavements of the improved type made of asphalt-concrete or bitumen-mineral mixtures with a thickness of 8-12 mm are usually installed on prefabricated bases. To a considerable degree, these pavements correct the unevenness of the prefabricated base. However, an uneven base nevertheless worsens the evenness of the pavement, especially a single-layered one, thus when checking the evenness of prefabricated bases it is not recommended to allow a gap under the 4-meter measuring rod of more than 7-10 mm. In cases of unsatisfactory evenness of the base, it must be evened by laying a thin (2-3 cm) leveling layer of bitumen-mineral, fine-grained mixtures and only after this should the pavement be laid.

The technological requirements for manufacturing prefabricated bases from bitumen-mineral slabs are much lower. They are laid by self-propelled cranes on a carefully levelled underlying layer of sand, gravel-sand material or slag, and in some cases directly on the earthen road bed. The slabs are seized by special metallic eyelets. A vacuum-clamp can also be used. The contact of the slab with the lower level is not checked. Plastic deformations take place in the laid slab under the effect of gravity in the warm season of the year facilitating its tight fit to the underlying layer. This process can be accelerated by passage of truck traffic along the slabs.

The uneveness of the base surface made of bitumen-mineral slabs reaches considerable values (the gap under the 4-meter measuring rod equals 10-30 mm and more). The width of the junction fluctuates from 5 to 20 mm, and in individual cases it is more. Thus in all cases it is obligatory to construct a leveling layer on such a base with a mean thickness of 2-5 cm made of fine-grained bitumen-mineral mixtures. When distributing the material of the leveling layer, it is also necessary to fill the wide gaps between the slabs along the surface of the slabs.

Laying a pavement on a prefabricated base made of bitumen-mineral slabs only after a technical check has established that the surface of the evening layer responds to the requirements for evenness and to observation of the transverse and longitudinal inclinations.



Figl 125.--Laying a prefabricated gage pavement with a truck crane.

In the majority of cases, laying of the slabs of prefabricated gauge pavement is accomplished by self-propelled automobile and track-laying cranes similar to laying continuous prefabricated pavements (Fig. 125). At the same time, the works in constructing prefabricated gauge pavements have some specific special features. In the majority of cases, gauge pavements are constructed on temporary roads, where there is mostly trucktraffic at low speeds. This makes it possible to somewhat reduce the requirements for their evenness. Practically, an unevenness of up to 1 cm is allowed on slab junctions on concrete gauge roads with the construction of heavy hydroelectrical stations (also on many forest roads). When laying slabs with an irregular contour of the lower surface (for example the latticed slabs of A.V. Yakovlev), the necessity of carefully checking their support tightness on the base becomes superfluous. The check for tightness of support is much easier with a small width of the slabs from constructions of smooth, continuous slabs. With the installation of prefabricated gauge pavements, these special features make it possible to discontinue check lifting and repeated laying of the slabs or to greatly reduce the number of them.

The laying of gauge pavements on curves can be carried out by two methods. On curves with a radius of 300-400 m and more, the slabs are laid with the installation of junctions of varying widths between them. A small width of the gauge pavement makes it possible to use this method of laying at radii of the curves less than permitted when laying main pavements. On curves of small radii, and also in whose cases when the opening of the junction is not permitted according to the working conditions of junction installations, a curvilinearity is lent to the gauge pavement by laying transverse, wedge-shaped slabs on the junctions. An example of such a design is shown on Page 126.

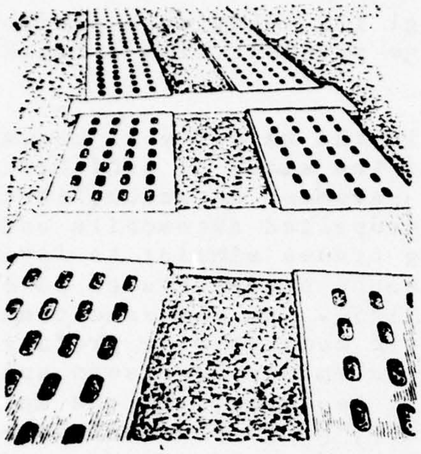


Fig. 126.--Construction of a prefabricated gauge pavement on a curve.

Dismantling of prefabricated pavements is carried out with their repair, and also when repairing or laying underground lines (pipelines, cables, etc), in the limits of the travelled part of highways and city streets.

Prefabricated pavements of temporary roads are subjected to complete dismantling at the conclusion of their period of service. The exploitation of prefabricated pavements on temporary objects along constructed highways may serve as an example of multiple use. With the forward movement of traffic and the introduction of the pavement into temporary use, the prefabricated pavement on the base of the road on the detour is dismantled, transported further and laid on a new part.

On temporary roads with a short service life, i.e. with frequent repetition of the assembling and dismantling processes, it is customary to use reinforced concrete slabs of the Yakovlev design, flat continuous reinforced concrete slabs or inventory metal pavements. Wooden, panelboard pavements are used much more seldom.

In a majority of cases they use automobile or tractor gantry cranes for dismantling prefabricated pavements of all types. When selecting the crane type according to lifting capacity,it is necessary to take into account the weight of the slab as well as the cohesion forces between the slab and the base. Their value depends on the type of base, the time of the year, the periods and the character of exploitation of the given pavement. Great difficulties emerge when dismantling prefabricated pavements laid directly on cohesive ground (loam or clay) and with use in a rainy period under heavy and intense traffic. Slabs with a complex contour of the lower surface also have increased cohesion with the base (caisson, latticed, etc).

In the winter, with a frozen base, it is possible to lift slabs laid only on dry, sandy base, excluding the possibility of freezing. The use of high-powered cranes for removing the frozen slabs from the base may lead to their massive damage. Artificial thawing of the base is possible, but in the majority of cases it is economically unprofitable.

Mathematical determination of the forces necessary for separating the slabs from the base does not always give correct results and requires additional experimental checking. By way of orientation it is possibletoo consider that the lifting capacity of the crane used for dismantling the prefabricated pavements must be 2-3 times more than the weight of one slab.

Dismantling of prefabricated pavement begins with dismantling of the junction connections. The bolt connections are unscrewed. The welded connections are cut by an autogenous welder or are dismantled pneumatically (or electrically). If the place of connection is with a cement solution, fine grained concrete or some kind of cement, this connection is first broken pneumatically or with an electric air hammer.

After dismantling of the joint connections on the slab, it is lifted from the base by a crane. For this purpose, the crane is placed as close as possible to the slab to be lifted, so as to work with minimum flying out of the boom and with maximum use of its lifting capacity. The crane hook, equipped with special attachments, seizes the slab from one end (by the eyelet outlet of the reinforcement or by the aperture in the lattice slabs etc.). A corresponding clamping device must be made for each slab design.

The slab, picked up by one edge, is torn up from the base, and then is let down again (Fig. 127). The clamping hook is rehooked so that it was possible to lift the slab without slanting, the slab is removed from the base and is laid on the shoulder of the road or is loaded into an automobile, trailer or the like (Fig. 128).

The pavement is dismantled by a brigade of three men: the crane operator and two helpers. The productivity of such a brigade with one automobile or tractor crane is for example 10-15 slabs of average size per hour.

In connection with the considerable forces emerging in the slabs with dismantling of the pavement, it is practically impossible to completely avoid damaging them. The edges and the corners of the slabs deform. Some of them are considerably damaged, which already is not suitable for their further use. The amount of damaged slabs basically depends on the quality of work of the crane operator and of his helpers. With careful dismantling, the percentage of damaged slabs may be small. On an average, the losses with each relaying of concrete and reinforced concrete slabs amount to 2-5%. The minimum waste happens with the first movement. The percent of loss increases with an increase in the number of transfers.

Dismantling of the inventory metal pavements is accomplished much more easily. In the majority of cases, such slabs have special eyelets for grasping them with a crane. The cohesion of the metallic slabs with the base is usually less than with concrete ones. Safety of the metallic pavements with dismantling is higher. The maximum damage is observed with dismantling the wooden panelboard pavements.

Stacking of slabs of small dimensions used in the base for the covers of sidewalks and park roads, is preferably done by hand. The use of conventional book cranes for their stacking with clamps for special eyelets is impractical. In the majority of cases, such slabs are not reinforced. The installation of special eyelets for their lifting requires inclusion in the nomenclature of expended materials of additional steel (or something else) reinforcements. The time for grasping with a hook on the eyelet and then for their uncoupling fluctuates little with a change of dimensions. Thus, its expenditure

on 1 m^2 of pavement is sharply increased with a decrease in the slab dimensions.

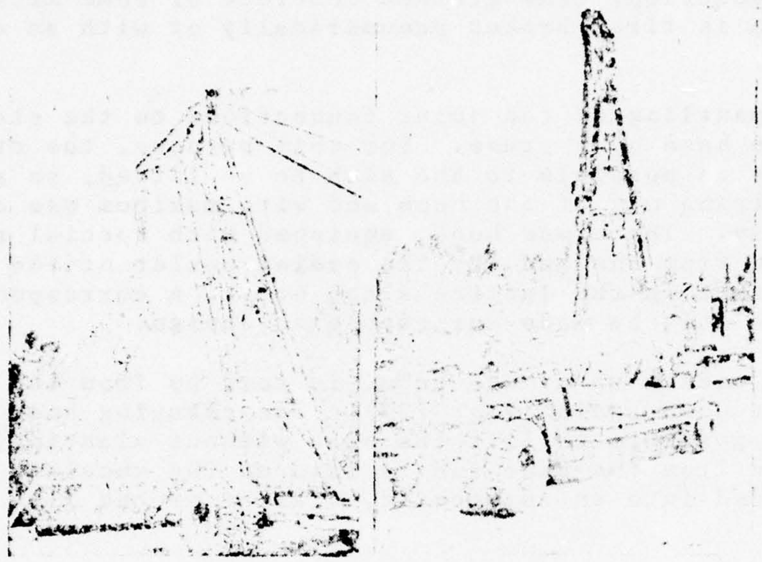


Fig. 127.--Dismantling of a prefabricated concrete pavement (tearing up the slab from the base with a T-75 crane).

Fig. 128.--Loading the slabs of a dismantled pavement on a heavy trailer.

It is expedient to use a vacuum clamp for laying small slabs, mounted on light moving boomcranes. Such equipment makes it possible to stack slabs on a sidewalk, on park roads and shoulders, the dimensions of which are determined by design of mathematical calculations, and not limited in the technology of carrying out the work.

26. Joining of Contiguous Slabs and Fixing Joints of Prefabricated Pavements

The completion stage in the technological scheme of installing prefabricated pavements is the work in joining the contiguous slabs and fixing the joints. The makeup of thie work, its organization and the technology of its completion are determined by the slab designs and the joint connections, the presence of materials and mechanization means, and also the climatic conditions when the work is being carried out. When building the prefabricated pavements in winter, the work in laying the joints is sometimes put off until the onset of the warm season, for technological considerations.

The work in joining the contiguous slabs must be carried out at once after their laying. As a result of this, the following must be provided: smoothness of the pavement in the zone of the joints, stability under traffic, redistribution of the forces caused by the moving load in the edge and corner zones of the slabs. Care in doing the work of joining the slabs essentially influences the quality of the entire prefabricated pavement. After joining (with good quality of the work) it is possible to open traffic over the pavement, without the danger that this can lead to the emergence of increased stresses in the slabs (compared with the calculated ones).

The design of the joints was examined earlier in Chapter 1. In the case of some of them, the contiguous slabs are connected by mutual engagement of the recesses found on the side walls and of the summits of different shape. The work in joining such slabs enters into the process of laying and is completed together with it.

In other designs, it is necessary to do special work for connecting the contiguous slabs: welding of the inserted component parts, screwing of a threaded coupling, insertion of dowels, etc. This work is carried out by special working crews or units after laying the slabs.

Independent of the design of the joint connection of the slabs, the junctions between them must be filled with special materials in order to guarantee their water impenetrability. The work in fixing the joints is done at once after completion of the jointing. Ruptures in the time between laying the slabs and fixing the joints are undesirable, since water-logging of the base may take place in this period. In addition, the joints left unfixed for a long period of time may be obstructed with fine crushed rock, sand, ground, etc, which causes the necessity of additional work in cleaning them out before fixing the joints. With an increase in the temperature and widening of the slabs (narrowing of the joints), the solid piece materials in the joints are the cause for the emergence of concentrated stresses in individual points and may cause their destruction (chipping).

Elastic-viscous materials are used for filling the joints (different cements, linings, prepared on bitumen or special rubber-bitumen astringents), as well as solid materials (cement solutions). Filling the joints with cement solutions is used mainly with the installation of prestressed joints or when laying slabs of relatively small dimensions.

Since filling the joints with solid materials (hardened cement solution) prevents expansion of the slabs with temperature increases, it is necessary to construct special expansion joints in such designs of prefabricated pavements (similar to monolithic concrete pavements) and to fill them with elastic materials.

In the majority of cases, the junctions are not filled in the prefabricated cases of road covers, taking into account that the pavement lying above it will sufficiently protect it from the penetration of moisture and impurities.

The technology of the work in joining the slabs and fixing the junctions of extensive designs is explained below. The most approved method for connecting concrete and reinforced concrete slabs is welding a specially laid clamp or ends of the rod reinforcements ends jutting from the concrete. The welding is carried out are laying the slabs and providing their necessary contact with the base (with the aid of vibration-laying machines, rollers, etc). Beforehand, the "window" of the joint connections is cleaned out with scrapers and brushes (with a steel pile) and the dust, dirt and sand is removed. Then it is blown out with compressed air from the compressor. If the gap between the brackets is not more than 4 mm, they are welded with one continuous junction. The length of the gap is taken to be equal to the length of the bracket, the width is assumed to be 0.5 of the diameter of the braket (but not more than 10 mm), the height--0.25 of the diameter of the bracket (but not less than 6 mm), the depth of the welding penetration not less than 5 mm. With a gap of more than 4 mm, an additional steel rod is placed on the bracket, the diameter of which is 2-3 mm larger than the width of the gap. The brackets are welded with parallel junctions (along both sides of the rod). In order to weld the protruding ends of the reinforcements, two additional steel rods are placed on them (see Fig. 50). The diameter of the rods is assumed to be for example 1/4 smaller than the diameter of the working reinforcement. The additional rods are welded with the working reinforcementwith longitudinal continuous junctions.

The selection of the mechanization means and the makeup of the brigade welding the joint brackets and the reinforcement outlets are decided individually in each concrete case. For example, the composition of the brigade with a productive capacity of 390-420 junctions with the junction brackets per shift is 3 machinists, 4 electric welders, 4 road workers. The mechanization means are: a D-378 electric brush, a PSK-5 compressor (or PSK-6M), a welding aggregate ASB-300 and a PES-15 power plant.

After welding the reinforcements, the junctions between the slabs are filled with a solution of Portland cement brand 500 and higher. The slabs of similar design (i.e. with welding connection of the reinforcement of contiguous slabs and filling of the junctions with a cement solution) may be conventional (unstressed) or prestressed, depending on the technology of carrying out the work, which excludes the possibility of the emergence of elongation stresses. The material filling the junction (except for the reinforcement) always must be compressed.

The quality of the pre-stressed junction is much higher than the conventional one. In the period of pavement use, the material filling the gaps (independent of temperature fluctuations and the corresponding changes in the linear dimensions) will always be in

a stressed state. With careful filling of the junction with a high-quality solution, the strength of the junction will be equal to the strength of the connected slabs, and the compressed zone of the junction will be prevented from forming cracks. The strength and smoothness of the entire pavement is increased with preliminary stressing of the junctions.

The technological process of installing a prestressed junction by stressing the reinforcement can be subdivided into the following basic operations: welding of the reinforcement (or its connection by another means) for example by threaded connecting pieces); stressing of the welded reinforcement, connecting the contiguous slabs, with the aid of jacks, laid in the junctions; filling of the junction and its hardening; removing the jacks, after which the elongated reinforcement tends to return to its original length, compressing of the closing device, filling the junction.

At the present time, different designs have been worked out with technological schemes corresponding to them for carrying out the work installing the prestressed junctions. An explanation of some of them is given below.

Prestressed junctions of the "Mosinzhproekt" design are arranged as follows when installing the prefabricated pavements from prestressed reinforced concrete slabs. The ends of the working reinforcement, projecting from the butt ends of the slabs at a distance of 60 mm, are welded with each other. Two flat jacks are inserted into the gap formed between the slabs (with a width of 140 mm), with which the butt end grains of the slab are unclamped with a general force of 68.6 t. The space between the slabs is filled with a rapidly hardening concrete of brand 400 with careful vibration packing. After the concrete has hardened, the jacks are removed, and the remaining recess is also filled with concrete. The prestressing of the butt end grains of the slabs with concrete, after removal of the jacks, is transferred to the concrete of the junction. The sequence of carrying out the work of installing such a junction is shown in Fig. 129.

The described design of a prestressed joint has two serious shortcomings: the necessity of leaving a gap with a width of not less than 140 mm between the butt ends of the slabs, which greatly increases the work done in the process of installing the pavement in laying the concrete mixture (design shortcoming); the period of time in doing the work of joining the slabs (technological shortcoming), the double time of hardening of the concrete (fixing the joint and fixing the depression after removing the jacks).

In the stressed joint with welded connections, worked out by the All-Union correspondence engineering-construction institute, the stress is created with flat jacks which are left between the slabs for the entire period of pavement use. Flat-turned steel tubes of a design of the Paton AN USSR welding institute, mass produced by our industry, are used as a flat jack for creating stresses with the aid of a solution.

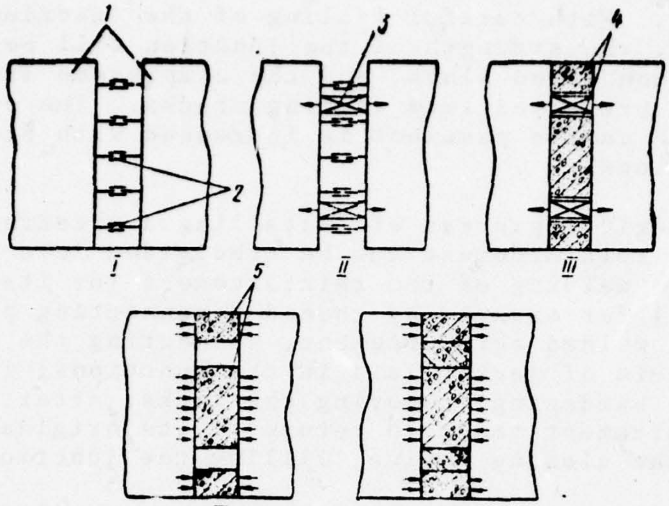


Fig. 129.--Sequence of work in installing a prestressed junction of reinforced concrete slabs: 1-welding of the reinforcement; II-installation of jacks and stressing of the welded reinforcement; III-filling of the joints with a concrete mixture (in addition to the places where the jacks were set uo); IV-removal of the jacks (elongated reinforcement tending to become shorter, compresses the concrete in the gap); V-filling the places where the jacks are set up with a concrete mixture; 1-reinforced concrete slabs; 2-welded junctions of the reinforcement of contiguous slabs; 3-jacks; 4-freshly laid concrete; 5-concrete reaching the calculated strength.

Fig. 130.--Element of a flat-turned tube, fulfilling the role of a flat jack (before installing in the junction the tube is straightened out).

Fig. 131.--Mechanism for pumping the solution under pressure into a flat jack installed in the junction.

The flat turned tubes are cut to the necessary lengths, the ends are heated up with electrical welding, and a connecting piece with a thread for connecting the hose from the solution pump is welded onto the middle part of the tube (Fig. 130). The prepared flat jacks are installed in the junction. There are two installation variations: in the first, the jack partially projects out of the junction (4-5 cm), in the second, the upper rib of the jack is found at one level with the surface of the pavement. The technology of finished the junctions changes as a function of the level of moving the jack. All other operations remain unchanged. After installation of the jack in it, the solution is heated up with the aid of a special injection solution pump. To avoid canting with incurstion of the crane or other construction transport means, up to stressing, the slabs are rigidly connected with each other by means of welding the outlets of the reinforcements or of the special laid components parts along the corners.

Different apparatuses are used in contemporary construction for injecting the solutions, but the most widelv used ones are aggregates connecting the solution mixer with an apparatus for feeding the solution under pressure (so-called injectors). Fig. 131 shows one such apparatus. It consists of two cylindrical tanks of like size and shape, the upper one of which is the mixer itself, the lower one plans the role of a bin for the finished solution. The mixer is calculated for 100 kg of cement. Beforehand, the dosed dry components (cement and sand) are fed simultaneously with the necessary amount of water into the mixture, where with the aid of blades situated on the vertical shaft, they are mixed for 10-12 min (rotational speed of the shaft 200 rpm).

For preventing stratification of the grout in the lower basin a billow with blades is also installed. As a result of rotating it with the speed of 100 rpm, at the time of injection the solution in the bunker remains in constant whirling movement. The rotating of the blades is maintained with the aid of a motor which is installed in the aggregate and run from a portable power station. The feeding of the solution into a unit of flat-displacement conduit is realized by a hand orifice pump mounted on the same frame with the solution mixer. After obtaining the necessare pressure (which can be read with the pressure gauge mounted on the solution pump), feeding of the grout is stopped.

Fig. 132. PART OF PRE-FAB COVERING AFTER TENSING THE JOINTS
(flat jacks, protruding from the seams, are visible.)

Then the valve on the unit of flat-displacement conduit is closed and the grouting device is moved to the next joint. Such a device is transportable, compact, has little weight, is reliable and can be used in full not only for the stressing of joints but also for other road construction work connected with the preparation and feeding of a solution under pressure, in part, for the injection of mortar under slabs.

In fig. 132, is shown a part of pre-fab covering after the injection of the grout into the joints. For injuection of the grout into the unit of flat conduit of one joint, from 3 to 5 minutes is necessary. For the operation of the installation (preparation and injection of the grout) 2 to 3 road construction workers of class IV are necessary.

Proper selection of the composition of the grouting mixture and careful observation of the demands of the technology of its preparation are mandatory conditions for the making of pressed joints of the given construction.

The grout is based on Portland cement of a brand no less that 500. The grout should have mobility (fluidity), little dehydration, frost resistence, little shrinkage, compressive strength after 7 days maturity no less than 200-230 kg/cm^2 and after 28 days maturity -- no less that 350-400 kg/cm^2. According to the data of the Institute for Scientific Investigation of Reinforced Concrete, the composition of the grouting mixture of 1:0.2:0.4 (Portland cement plus ground sand (or sand with granule courseness up to 0.5 mm) plus water) can be recommended for the installation of pre-stressed joints. All materials (Portland cement, water, sand) should be measured only by weight. Investigations have shown that with such a composition and the correct technology the strength of the hardened grout in the unit of flat-displacement conduit can reach 600 kg/cm^2.

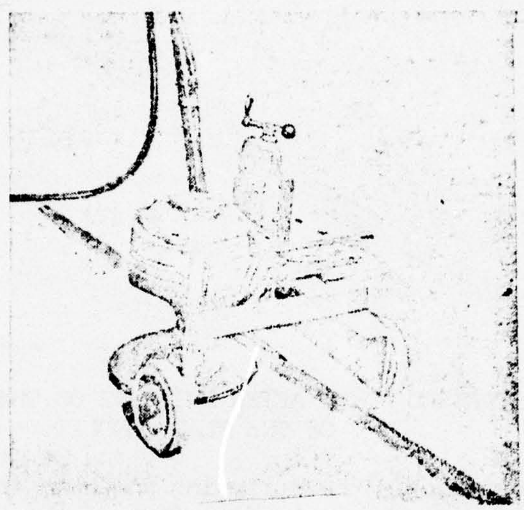


Fig. 133. SHEARING OF A SECTION OF FLAT-DISPLACEMENT CONDUIT WHICH PROTRUDES FROM THE SEAM

In joints stressed beforehand with jacks from flat-displacement conduits, which protrude from the seam higher than the surface of the slabs, the finishing of the joints and seams consists of shearing-off of the part of the conduit which rises out of the seam together with its packing grout, and in grinding of the surface of the seam (that is, the grinding of the face plane of the walls of the conduits, which have remained in the seam, and the grout between them).

The shearing -off of the part of the flat-displacement conduit which rises above the slabs is accomplished by a special machine (fig. 133) after the packed conduit has achieved the prescribed strength. This machine is equipped with an electric motor with the power of 1.7 kilowatts and 2800 RPM/min, two worm gears for horizontal and vertical moving of the electric motor, and a device for

installing the cutting (abrasive) and grinding disks. A portable power station supplies the motor with electricity. For shearing the machine is installed in such a position so that the guiding beam is compactly pressed to the left side of the protruding unit. With this accomplished, the abrasive disk should touch firmly the right of the lower part of the protruding unit. By a turn of the handle of the switch, the motor and the cutting disk are brought into a rotating movement along the indicator. Simultaneously the machine begins to move at a constant pace. At one passing it cuts one well of the unit. Then it is turned 180 degrees and cuts the second part of the unit.

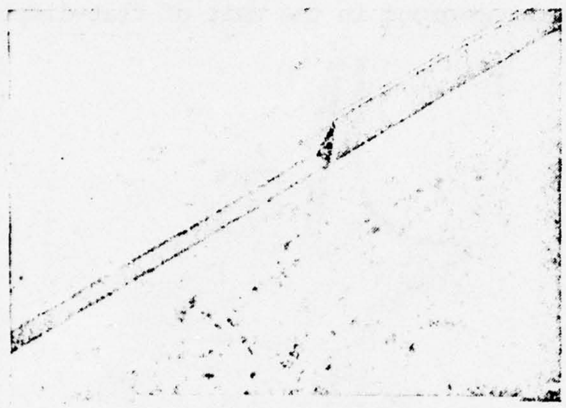


Fig. 134. STRESSED JOINT AFTER SHEARING OF THE PROTRUDING PART OF THE FLAT CONDUIT.

The last operation is the stripping and grinding of the irregularities remaining after shearing the protruding part of the flat conduit. For this, on the shaft of the motor is placed and secured an abrasive disk intended for the grinding of the surface area. In fig. 134 is shown the stressed joint after its finishing.

The technology of finishing the pre-stressed joints with fused coupling is significantly simplified when the flat-displaced conduits are arranged flush with the working surfaces of the slabs being joined. Such a construction allows for the possibility of avoiding the shearing of the protruding part of the donduit with the grout. All prepatory operations in this case are analogous to the operations for the installment of the joint with the conduit partially protruding. The preparation of the grout and the stressing of the joint follows the same sequence. However, in this case finishing can be conducted directly after stressing, not waiting for the final hardening of the grout in the conduit. This significantly shortens the overall length of time for execution of assignments and helps speed up the implementation of the surface into operation.

For framing the remaining, unpacked upper part of the hoint, high-strength grouts, prepared on the basis of epoxide resins, can be used. In view of one of the possible compositions for the preparation of such a grout, the compound K-139 in a mixture with loose sand and dolomite flour (in the ratio of 1:1.5:0.5) can be used. In view of a hardening agent, ployethelene-polyamin in the quantity of 0.15 of the weight of the compound is used.

According to the data of the Institute for the Scientific Investigation of Plastics, compound K-139 is characterized by the following coefficients: strength under bending, 540 kg/cm^2; strength under compression, 640 kg/cm^2; strength of aglutination for separation, 31.9 kg/cm^2; elongation under conditions of breakage, 4%.

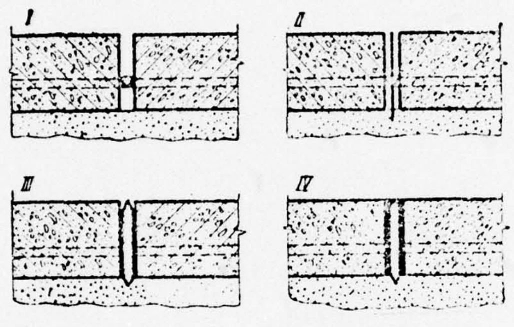


Fig. 135. DIAGRAM OF THE INSTALLATION OF STRESSED JOINT WITH THE AID *OF JACKS MADE FROM FLAT-DISPLACED CONDUITS.*

I.- fusing of laying components of contiguous slabs; II. - installation of flat jack; III. - stressing of the joint (filling of the flat-dis placement conduit with grout under pressure); IV. - finishing of the joint (filling in of the upper part of the seam with strong grout)

In preparation the composition for the framing of the joint, at first the compound is mixed with the hardening agent (polyethelene-polyamin) and evenly stirred over the course of 20-30 min. Then the sand and the dolomite flour is added and again stirred until a uniform substance, ready for use, is obtained. Before filling the joint it is necessary to clean the surface of dust and dirt, and coat the borders with the compound. The technological sequence of the installation of the joint with the installation of the unit of flat-displaced conduit flush with the surface of the joined slabs is shown in fig. 135.

Another variant of the construction of the joints of rigid segmented coverings is the pre-stressed joint with threaded coupling of fittings. They can be employed in constructions of segmented coverings of the permanent type and also in constructions of the segmented-dismountable coverings of roads of the temporary type. The essential advantage of the threaded couplings is the convenience of the production tasks in the dismantling of the coverings when it is necessary to repair or transport them. Aside from that, in stessing the joints (in contrast to joints with fused coupling of the fittings) installment of jacks is not necessary. The stressing of fittings is acheived by means of elongating the threaded couplings.

The correctness of making the couplings and the precision of their installation are some of the first priorities in erecting of the pre-stressed joint in order to obtain the highest quality for the given construction. The principle units of the stressed, threaded joint coupling are couplings of the glass type (Fig. 136) and thrust washers.

Every coupling consists of two connecting pieces. On the larger connection is rifled the inner thread, on the smaller - the outer thread, of the same diameter. The connections are placed on the ends of the hoining fitting rods, then the thrust washers are placed in a projected position on the connections and welded on. The accuracy of their installation from the face plans of the slabs is checked by special gauge boards. On this, that is, how accurately and correctly the connections are placed on the ends of the joining rods, will depend the quality and effeciency of the stressed joints. Therefore, along with the correctness of the making of the threaded couplings, in the process of making the slabs serious attention should be given to the installation of the connecting units in the construction of the slabs.

Fig. 136. THREADED COUPLING CONNECTION UNITS

Since in the process of erecting the coverings it is entirely possible to displace the joining rods, the diameter of the openings in the connecting pieces for their installment on these rods are made 4-5 mm larger than the diameter of the fittings.

The threaded coupling units have a rather simple form and can be made in machine and fitting shops of factories which produce segmented, pre-stressed concrete. In the mass application of pre-stressed concrete slabs with stressed coupling, the threaded coupling units must be produced by the method of stamping, precision casting or pressure die-casting.

The installation of connections into a projecting position can be realized either before the formation of the slabs or after their production (after the striking of the workpiece). It is easier to install and secure the connections in a projecting position after making the slabs. In this case it is possible to avoid the influence of defects which can arise in the process of making the slabs.

To preserve from contamination connections (their threads) or the sleeve type and also to protect them from the harm incurred in loading and unloading and transport tasks, before dispatch to the warehouse or the construction site it is recommended to coat them with machine oil and wrap them with oil paper.

Threaded couplings with connections of the sleeve type give the possibility of obtaining significant preliminary stresses in the joints. Besides this, thanks to their small size, the volume of work on the framing of the sockets in which the connections are placed is significantly shortened.

Before the stressing of the joint, for the insurance of water impermeability, the seam is made strong and impervious to water. Usually for this purpose a cement-sand grout, produced with Portland cement of the 500 brand or a quick-hardening cement, is employed. The grout can be prepared with help of a portable injecting installment of the design described earlier in this passage. In using the Portland cement of the 500 brand, the grout mixture of 1:0.2:0.4 is recommended (Portland cement plus ground sand or sand with granule courseness up to 0.5 mm plus water).

The technological process for installing pre-stressed joints with threaded couplings of the permanent type consists of the following operations: a) mounting of gauge boards in the seams during the procedure of mounting of the covering with slight tightening of the threaded couplings with the aid of everyday spanner wrenches; b) loosening of the threaded couplings and removal of the gauge boards; c) filling of the seams with cement-sand grout; d) tightening of threaded couplings up to the calculated magnitude with the aid of calibrated wrenches; e) waterproofing of the remaining sockets. After the laying of the first transverse row of slabs on the whole width of the driving suffface, place the next row with a small gap (6-8 mm), necessary for the pouring of the grout. The necessary width of the seam is obtained with the aid of metallic gauge boards (fig. 137). In the given drawing the thickness of the gauge is shown at 8 mm. It can be lowered into the seam up to a depth of 100 mm. The gauge boards are placed in the gap between the slabs close to the location of the threaded couplings. In the process of joining, up to the point of stressing, the level of the covering at the joints is checked with the aid of a 4-meter batten. Recesses should not exceed 2-3 mm (depending on the type of road), the gap under the batten in any place on the covering - 5 mm, the seams should be straignt lines, and the edges of contiguous slabs -- parallel. Seams and edges of the slabs should be clean. The threaded couplings are tightened with spanner wrenches in order to guarantee the width of the seam, equal to the thickness of the gauge board. Then they are slightly loosened, the gauge boards taken out and ready for the pouring of the seams. After the grout has achieved the proper strength (no less that 40-50 kg/cm^2) it is ready for the stressing of the joints. It is realized with the aid of special calibrated wrenches. There are various designs of such wrenches. The simplest and most reliable is the calibrated wrenches with adjustable moment. The moment wrench, equipped with a special spring,

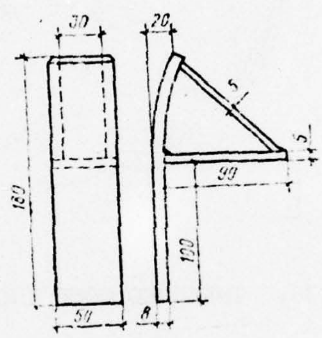


Fig. 137. METALLIC GAUGE BOARD (all dimensions in mm, the 8 mm thickness of the gauge determines the width of the seam.)

is calibrated directly for the calculated torsional moment; when reaching the torsional moment in the process of turning the threaded couplings the spring is triggered and the wrench carries through.

For this end the design of a moment wrench with clock-type indicator can be recommended, (Fig 138). In the design of this wrench the torsional moment is determined by the camber of the handle grip. Beforehand the wrench is calibrated for the tension which increases after a determined interval. At each stage of tension departures of the indicator arm are fixed. On the basis of the data on magnitude of the tension at the end of the wtench handle and the readings of the indicator, a calibration table is composed, in which is determined the calculated moment necessary for the desired forces in the joining rods during the process of stressing the joints.

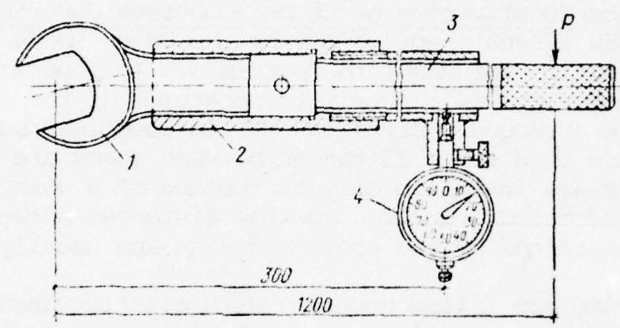


Fig. 138. CALIBRATED WRENCH:
1 - spanner wrench; 2 - detachable housing; 3 - handle; 4 - indicator.

Tightening of the connecting pieces, located in one point of junction, is produced in several ways. With two places of juncture it is necessary to tighten by turns, in several stages, first one then the other junction. With three points of junction tightening must begin with the two extreme points. Once they are tightened to the point of calculated magnitude, the middle one is tightened. This process is repeated several times, until all junctions reach the desired magnitude. After stressing all the joints it is possible to allow the movement of automobile transport along that section, while not closing up the remaining sockets. As a result of this, final redistribution of forces in the concrete and fittings in the area of the stressed joint can be made. Before the remaining holes are closed up with grout, the stresses in the hoining rods are verified with the help of a calibrated wrench.

After the installation of the pre-stressed joints, the segmented covering works as a whole monolithic one. With changes in temperature

in the covering, considerable stresses develop in the covering, stresses which can lead to the formation of open transverse fissures, buckling of individual portions of the covering and its fracture. For the reduction of stresses, prevention of fissures and the increase of linear stability of coverings, transverse seams of expansion are utilized. Their use allows for the possibility of the expansion of individual portions of the covering with a rise in temperature of the air at the time of installation, its construction design (thickness, type of reinforcement) and type of bedding. An essential consideration is the fluctuation of temperature of the air and the surface material.

In choosing the distances between the expansion seams in segmental concrete coverings, it is possible to consult the recommendations of the Instructions for the Construction of Cement-Concrete Coverings of Automobile Roadways (VSN 139-68), worked out by the Union Roads Institute of Scientific Investigation for Monolith Coverings. In accordance with these instructions, in covering built in air temperatures of the +10°, +25°c range expansion seams are arranged every 40-80 m. In coverings built in air temperatures of more than +25 c distances between seams are not standardized and such seams are installed only at the end of a work shift. In coverings of the pre-stressed concrete type the distances between expansion seams is always determined by the project design and usually reach 100 m or more.

Expansion seams are filled entirely with elastic-viscuous materials, which do not inhibit the expansion of the slabs (reduction of the width of the seam with increase in temperature). In view of a elastic-viscuous material, prepared spacers of various sorts of mastic are often used (See Ch. III). Such materials are used to fill in not only expansion seams in segmental coverings with pre-stressed joints, but also any seam between contiguous slabs of the rigid variety (concrete, silicate-concrete, slag type), only if the design does not call for filling in with cement grouts. Mastice used at the present time do not always meet (insufficient degree) the standards claimed. In hot weather they are partially squeezed out of the seams and smeared over the surface of the covering by the automobile tires. As a result of the loss of material to fill the gap. When installing the coverings it is mandatory to check systematically the filling in of the seams and, if necessary, fill in additional mastic.

The mastics most often used are those applied in a heated form. When filling in the seams between slabs, to economize the mastic, the lowet part of the seam is filled in with a cement-sand mixture. The composition of the mixture is 200-300 kg cement for every 1 m^2 of sand. The sand and cement are

mixed in a grout mixer. The prepared mixture fills in the seam to the necessary depth. In order to speed up the setting process and stave off the expulsion of the mixture, it is moistened.

The technological procedure for filling in the seams (either partially or in full) consists of the following operations: cleaning of the seam, laying of its walls, heating of the mastic (or its preparation) and introduction into the seam. The technology of cleaning the seams depends on to what degree they have been clogged. If between the laying of the slabs and the filling in of the seams, a considerable period of time has passed and traffic has been permitted along the covering, then the seams can be clogged and their cleaning is labor-consuming. For the preliminary cleaning various mechanical and electrical wire brushes are employed. The final cleaning is accompliished by blowing off the seam with compressed air obtained from a portable compresser.

To minimize the task of cleaning the seams, it is necessary to fill them in soon after laying and joining the slabs. Laying of the walls of the seams, for better adhesion with the mastic, is done by means of coating with bitumen BND 40/60 or BND 60/90, or diluted gasoline. Sometimes the edges of the sides of the slabs are coated in the factory or in the warehouse before being sent for laying.

The majority of the mastics can be applied to the road in prepared form and need only be heated for the reduction of their viscosity and to facilitate filling in the narrow seams. Mastic TsN-2 is prepared at the construction site in the following manner: 1) pure bitumen is heated and dehydrated in a bitumen heating kettle. Bitumen of the brand BND 40/60 at a temperature of 100°-140°C; 2) the alloy B-1 is added to the melted bitumen, and the mixture is constantly stirred and heated to a temperature of 160°-180°C; 3) to the prepared mixture is added an already heated filler (sand) and, maintaining a temperature of 160°-180° C, the mixture is stirred until it reaches a substance of uniform texture. After this, it is ready for use.

Mastic TsN-2, "Izol", and also other mastics prepared on a base of viscuous bitumens, is poured into the seams at a temperature up to 160°-180° C within 2-3 hours after the preparation of the seam walls. For filling in the seams with heated mastic, the most often used equipment consists of a small bitumen kettle, hand mixer and a directing nozzle. The mastic is poured into the seam either by its own flow or under pressure (to ensure a higher quality of filled-in seams). When the seams are being filled in, it is necessary to watch the temperature of the mastic because the cooling process increases the viscosity of the mastic and the seam receives a poor filling. If, in the procedure of laying the slabs, standards of width were not followed (the seam are too narrow, less that 5 mm), then filling in will entail great difficulties. It is impossible to prepare the seam walls with diluted bitumen, hot mastic in thin seams cools quickly and does not fill the entire depth of the seam. In such a case, it is recommended to use a cold mastic to fill the seams. Cold mastic is prepared on the base of quick decomposing bitumen or slow decomposing bitumen emulsion with an addition of latex SKS-65 in the quantity of 15% by weight.

After the opening of the pre-fab covering to traffic, the covering laid on sand or a similar bedding, will undergo slight settling at the expense of a more compacted upper level of bedding and a flatter fit for the slabs. If this occurs a partial settling of the mastic which fills the seam can take place. Therefore, after 2-3 weeks after the opening of the road to traffic, the condition of the seam filling should be checked and, where necessary, mor filling added.

Seams of segmental foundations intended for the installation of a covering of an improved type (asphalt-concrete, bitumen-mineral mixtures, crushed rock with a finished surface) often do not require a filling of a special nature. The coverings sufficiently guard the seams of the doundation from surface moisture.

Seams of the coverings of sidewalks and park paths with small-sized slabs are usually filled with a cement-sand grout. The principle regard in this choice is to increase the strength of the slabs of small size and weight, rigidly securing them in the general structure of the covering. Significantly less often for this goal builders use a bitumen mastic, because in hot weather the mastic is pressed out of the seam and smears the covering and footwear. Sometimes a filling composed of a small-granuled material is allowed: Sand, gravel, or soil. In the last case the width of the seams is increased and seed is planted for decorative grasses.

27. CONSTRUCTION PRE-FAB COVERINGS AND FOUNDATIONS IN WINTER CONDITIONS

Pre-fab coverings and foundations are road constructions which more fully respond to the demands of production tasks in winter conditions. Unit elements (slabs) are made in unit-construction factories where the influence of negative climatic factors (low temperature, percipitation, wind) can be substantially lowered or even ruled out completely. The great distance to transport pre-fab units does not limit itself to technological requirements but is in full determined only by economical considerations and the presence of means of transport.

The construction procedures in the assembly of coverings or foundations from pre-fab slabs are turned into mounting procedures. With due advantage they differ from production of roads in the construction of monolith pavement made from cement- concrete or asphalt mixtures by the fact that, in this case, technology depends less on weather conditions to a considerable degree. The shortening of operations performed directly on the road lessens the numbers of the needed working force. Additional expenditures called for by the rise in the work costs in pre-fab construction, as a rule, are lower than those which arise in the winter in the construction of monolith coverings.

The assembly of pr-fab coverings can be done under low, unfavorable temperatures. The temperature limit which rules out execution of work is usually about -25, -30 C (depending on the conditions of labor protection).

In general, the procedure of erecting pre-fab coverings (foundations) consists of the following stages: making and delivering the slabs, preparation of the bedding on which they will be laid, laying the slabs and installation of joints and seams. Under winter conditions, the very same enumeration of the types of work that exist in summer is retained, but the composition and technology of production in a whole series of cases substantially change.

Under winter conditions the execution of pre-fab construction is done mainly in specialized enclosed shops. Making the slabs in open areas is stopped. Of the exceptions, sometimes in such areas asphalt slabs are made. Transport of the ready structures is carried out in the same way as in summer, without any limitations.

The strength and rigidity of slabs made with organis adhesive materials (asphalt and asphalt-concrete) increases in the winter. Without deformation they take on the significant stresses incurred during lading. Therefore winter is the most beneficial time to transport asphalt and aspahtl-concrete slabs.

Under winter conditions requirements for the quality of the preparation of the bedding for laying the slabs significantly increase. Strength, longevity and the eveness of the segmental coverings built in winter conditions depend, in still greater degrees than in summer, on the condition and preparation of the graded bedding and foundation on which the slabs will be placed. Road coverings, including pre-fab types, in winter conditions should be arranged on a graded bedding and foundation constructed during a warm period of the year. Near the beginning of winter, the graded bed should be carefully packed and the surface of the bedding planed in accordance with the projected slopes.

When constructing the segmented foundations the slabs, in a number of cases, are placed directly on the graded bedding or on a thin layer of sand, which serves as a leveling layer. Such construction often come into play when asphalt is used for the foundation. In view of the best guarantee of water run-off on the surface of the graded bedding, a sythe-like contour in transverse section with slopes toward the outside shoulder, 20-30/oo in the middle part and up to 50/oo - at the edge of the shoulder, is recommended.

Run-off for the shoulder and the construction of a trough earlier, in summer weather, on the site of a winter construction of road surfaces can be permitted as an exception when earth which is good for drainage is used for the erection of a bank. When earth which is poor for drainage is used, the banks are measured off only up to the point of the trough.

An oven and compact surface of the graded bedding with the transverse slopes from its longitudinal axis to the shoulder falicitates the run-off of moisture from the falling percipitation and melting snow. A high degree of compactness lessens the penetration of moisture, held on the surface, into the embankment. Therefore it is recommended to apply the required coefficients of packing on the upper part of the bank (up to a depth of 1.5m) in zones II and III no less than 1.0 m, and in climatic zone IV - no less that 0.98.

For the preservation of an indestructible graded bedding surface, after planing and packing on sites where the laying of road pavement in the winter is planned, transport traffic must be prohibited (that is, traffic must be detoured) until the ground has frozen to a depth of no less than .30-0.40m.

In that case, when, in winter, segmented coverings will be placed on the foundation, the latter must also be constructed ahead of time in the summer. Its material must be packed and the surface planed according to the projected slopes.

The foundation layer (just as with the graded bedding) should be protected from harm by limiting motor traffic, especially during the fall when the roads become slush. The best types of foundations for laying slabs in winter conditions are compact and strong gardes of earth reinforced with cement or bitumen. Such foundations are only insignificantly deformed under the movement of automobile traffic and, possessing weak water-permeability, they protect the graded bedding from penetration of surface moisture.

In regions where moisture is heightened, at construction sites where the graded bedding is poured from cohesive earth and intended for laying of covering in the winter, it is recommended to lay water-impervious foundations, made from reinforced earth, the whole width of the graded bedding. On those roads being constructed where the foundation, made from compact non-draining materials, has a width equal to the width of the traversed area of the road, before the arrival of frost, fill in the shoulders. The surface of the shoulders should be planed to the same level as the surface of the foundation with a slope of 40-50‰ to the outer edge of the graded bedding.

On banks poured from loam-sand earth, a foundation made from draining materials (sand, gravel) is laid with a broadened area (in comparison to the width of the segmental covering) of 0.5 m to each side. In the shoulders planed at the level of the surface of the foundation, draining funnels are laid for run-off of water. In all cases, near the moment of freezing, moisture of the graded bedding should not exceed the optimal.

Regardless of the quality of the planing of the surface of the foundation layer (or graded bedding), directly before laying the slabs, an equalizing layer of non-frozen materials is placed on the foundation; dry sand, fine ground sand-cement mixture, dry sand-cement mixture, sand made with a fluid bitumen (2-4%) and so forth.

The implementation of this layer is not just to even out the surface of the foundation but also to guarantee flush contact between it and the lower surface of the slabs.

In winter the thickness of the equalizing layer is equal to 5-8cm, 1.5-2 times thicker than the usual thickness of equalizing layers laid under summer conditions. The thicker the layer, the more slowly it freezes. Good contact between the slabs and the foundation will be achieved only when the slabs are placed on such a foundation (non-frozen). An equalizing layer with a large thickness is a must when slabs are placed with bibro placing machines, because the efficiency of the movement of the vibro placing machines raises the thickness of the stretched out layer made from non-frozen materials.

In those cases when the entire layer of the foundation is to be laid with small-ganulee materials (sand, gravel-sand mixture), it is separated into two layers. The thickness of the lower layer is equal to the thickness of the foundation, and reduced by 8-10 cm. The lower layer is placed, planed and packed in warm weather. The upper layer is placed to a thickness of 8-10 cm and is composed of melting materials directly before laying the slabs.

In preparing the foundation during winter weather, its surface should be cleared of snow and ice 1-2 shifts before placing the equalizing layer in stable weather, and in case of frequent snowfalls and snowstorms this period is shortened to 2-3 hours.

It is necessary to clear the snow from the traversed part of the road and from the shoulders as well; the latter is for the reason that snow left on the shoulders can be mixed up (by motor vehicles, road-building equipment, wind) with the materials of the equalizing layer so that the quality of the latter is substantially lowered. Snow clearing is carried out by motor vehicles, ploughs, or rotary snow-removal machines. They can remove the major portion of the snow but do not guarantee careful snow-removal. Therefore, additional clearing of snow is carried out by mechanical brushes, mounted on the automobile snow-removers.

On the surface of the foundation often form thin layers of ice and frozen show, formed in the first days of winter because of melting. In this case, for snow-removal, snow-removal machines equipped with ice-scraping attachments and bulldozers or graders with toothed cutters can be used. However, complete removal of snow and ice is possible only after the ice and frozen show has melted on the surface of the foundation. There are two means of artifically melting the ice: chemically - with the help of various salts, and physically - by heating. The first consists of treating the upper layer of ice with a 20-30% solution of sodium chloride or calcium chloride (in the quantity of 1.0-1.5 l/m^2). Solutions of these salts lower the temperature of melting point of ice and in 2-3 hours after their application the ice shell breaks apart and can be taken off by grader or mechanical brush.

The remaining water on the surface is removed with mechanical brushes and hand scrapers.

In order to remove ice and packed snow, heating devices can be used, devices which melt the ice and snow and at the same time disperse the moisture which has collected from the melting process. Equipment used for this purpose on building projects can be divided into two groups according to the character of their hearing process: those that act on the ice directly with a flame or hot gases; and those that act on the ice with radiation.

Jet engines, which outlived their life on a jet(thermal engine TM-59), are an example of the machines of the first group. Such an engine, mounted on a self-propelled chasis of serial snowtruck (D-452), guarantees the clearing of 0;84 hectares of ice crust, 3-4 m thick, in 1 hour in temperatures of -5°C.

To the second group of machines belongs burners using infrared rays and running on gas fuel. They are usually mounted on motor vehicles or graders and are used for the melting of asphalt-concrete coverings at the time of repairs. Using up to 4 kg of gas per hour, they can dry from 40-200 m^2 of icy surfaces. The productivity of those using these drying agregates with burners operated with infrared rays is at the present time insufficient. Therefore, they usually work in teams of 2-3 aggregates in production conditions.

It is not recommended to employ thermal machines and heating devices to melt ice and snow on foundations based on the application of organic chhesives, because the action of high temperatures can destroy the upper layer of the foundation.

After the final cleaning of the surface of the foundation (from snow and ice) the work of laying the equalizing layer on the foundation begins. It is necessary to complete this task in a short period of time to preserve the material in a non-frozen state up until the slabs are placed. The length of the period of time in which it is possible to carry out the transport of the materials to the building site and the construction ot the equalizing layer itself depends on a number of factors: temperature of the air and materials, their moistness, thermal capacity and heat conduction, wind factor, thickness of the equalizing layer and so forth. The time the materials can be preserved in their thawed state can be determined. However, judging from its dependence on so many factors, it is always necessary to conduct control diagnoses.

Transport of the dry materials to the site in conditions of low, unfavorable temperatures (0-5°C) and transport in large trucks can take place 10-20 hours before beginning to work on the equalizing layer. Once the materials are unloaded they are kept in cones which are not smoothed out. In more unfavorable temperatures the materials are transported to the site 1-4 hours before the laying of the slabs.

The delivered material is leveled by bulldozers and a trailing leveler (by hand) or special grading machines moving on rails. After leveling, the material is packed with light rollers (3-5 passes over the same portion of the site). Also for this task are surface vibrators. When the shaping machines (equipped with vibrators) are used, no additional compacting is necessare. Laying of the slabs on the prepared equalizing layer should take place as soon as possible; the equalizing layer should not be left uncovered for more than 20-30 min.

For placing the slabs in winter the same machines are used as in summer; gantry and beam cranes, vibro-placing machines, etc. Technology of the construction and demands for its quality remain unchanged. In winter conditions, just as in summer, when the slabs are placed it is necessary to guarantee two basic demands: the slabs should lie flat on the foundation along their entire lower surface; the level of the pre-fab covering should be the same as that of a monolith covering made of the same materials as the pre-fab slabs.

In the construction of rigid pre-fab coverings of the major type, for the improvement of contact between the slabs and the foundation, vibration is used. Vibro-placing machines are employed. With this operation the slab will make vibrations of a high frequency on the foundation or the equalizing layer, which is based on a small, dry material (sand, small sand-gravel mixture). At this time there is a slight movement of the particles and due to the forces of weight and vibration, the slab lies more fulsh to the foundation. It is necessary to consider that in winter with frozen foundations and thawed equalizing layers of a relatively small thickness, the work of the vibro-placing machines have a smaller effect than in the summer. The time that the vibration is used must not be increased because this can lead to the breaking of the slabs. The small thickness of the layer worsens the conditions for the shifting of particles of material. In connection with this, the ability of the slabs to rest compactly on the foundation and the ability of the covering to lie level are also reduced. Vibration gives the best results under optimal conditions of miosture in the small-granuled materials of the equalizing layer. Because of the danger of quick freezing of the thin equalizing layers under winter conditions, thses layers are usually made from dry materials. Thawed, moist materials are employed with advantage under minor unfavorable temperatures (close to 0° C). When a dry small-granuled sand is used for the equalizing layer, it is necessary to make sure that with vibration of the slabs no sand is thrown from out ot the seams. Sand treated with bitumen gives the best results.

In summer conditions slabs are sometimes placed on equalizing layers made with plastic, cement grouts or sand grouts are injected under the slabs to fill in all the emply spaces between the slabs and the foundations. In winter conditions the use of such grouts can be permitted only

in air temperatures lower than $-10^{\circ}C$ and under careful technological control. NaCl and $CaCl_2$ salts are added to the grout to lower the freezing temperature. The quantity of additives is determined in the construction laboratory and depends on the composition of the grout and the outside temperature. Work connected with the use of grouts must be conducted at a quick pace. In the thin layers under low temperatures, grouts lose their fluidity, a result of which they do not receive a uniform distribution under the slabs. In such cases in spring, after the thaw, an irregular settling of the slabs can take place under the action of transport traffic.

The concluding work on the assembly of pre-fab coverings is the finishing of the seams and joints between the slabs. It is usually carried out in two stages. First of all, the junctions and the joint connections are secured and then the seams are filled in with materials which inhibit the penetration of surface water into the foundation.

The first operation can be decided on. In contemporary pre-stressed concrete segmental coverings, welded and threaded junctions are most often used. In some cases stressed joints are installed. In winter preference is given to the threaded junctions. Stressed joints used with cement grouts are employed with advantage in favorable air temperatures. If for some resson the use of grouts is unavoidable, in the finishing of slab joints, with unfavorable air temperatures it is necessary to raise its calcualted strength by 15-20% at the expense of having to employ a higher grade of cement (quick-drying cements) and introduce chloride salts (to lower the temperature of freezing).

For ensuring water-impermeability, the seams between the slabs are usually filled in with various mastics based on a bitumen or cement grout. In connection with the technological difficulties of filling in the seams in low, unfavorable temperatures, these tasks are often postponed until Spring, in connection with whcih at that time it is necessary to fulfill labor-consuming, additional work in cleaning the seams of collected dirt. Besides the above, it is necessary to consider the possibility that by Spring the foundation will become moist again. In case of considerable moisture, it is necessary to close the roadway to traffic until the foundation has dried.

In insignificantly unfavorable temperatures, filling in the seams takes place just after the slabs are in place, in which case, preference is given to the bitumen mastics, because cement grouts in thin seams quickly freeze. After thawing, the processes of hardening in the grouts continues, but because of the early freezing the final strength of the grout will be significantly lowered.

Bitumen mastics are used in the same fashion, whether hot or cold. The first mastics used in winter conditions are prepared with bitumens of a lowered viscosity (BND 130/200, BND 200/300). Hot mastics are introduced into the seams under compression (with the aid of compressors).

in the opposite case, because of their quick cooling, the seams are filled in poorly. It is possible to use cold mastics prepared on the base of a bitumen emulsion with an addition of latex SKS-65 in the quantity of 15% by weight (See Ch. III).

In all cases of winter construction of pre-fab coverings it is necessary to check carefully the filling of seams in the Spring after thawing and drying of the pavement. Where necessary, additional filling must be done.

In Winter, just after joining the slabs and filling the seams along the pre-fab coverings, traffic can be opened. If the fre-fab covering was laid on a strong, well compacted foundation and the graded bedding was built in accordance with the requirements of the construction norms and regulations, then traffic need not be stopped even during the Spring thaw. Settling of the slabs under traffic in Spring usually occurs if the slabs were placed on insufficiently packed or frozen foundations and graded beddings. Defects in the pre-fab coverings built in Winter are corrected in warm weather after complete drying of the whole road construction. The settled slabs are freed from their connections with neighboring slabs, lifted out by cranes; then, after leveling and packing of the foundation, the slabs are put back in place.

The technology of the installation of slag concrete and silicate-concrete slabs is similar to that of reinforced concrete and concrete slabs. The installation of asphalt slabs (for the construction of pre-fab foundations) differs from that of concrete slabs due to the fact that the requirements for an even surface and the compactness of the slab with its lower layer are reduced. In most cases the slabs are placed direclty on the graded bedding or foundation without the construction of an equalizing layer. Cleaning of snow and ice from the surface is done with removal equipment, the melting of thin films of ice is not necessary.

Asphalt slabs are installed in any unfavorable temperature and left uncovered until summer. With the arrival of stable warm weather the rigidity of the slabs is reduced and at the expense of deformations they lie more flush to the lower layer. In Spring, after complete thawing of the graded bedding and foundation, and after the cesation of pre-cipitation, on pre-fab foundations of the asphalt slab varieties an equalizing layer of small-grain asphalt is placed. Only after this is completed can work begin on the covering.

Work on the construction of pre-fab road pavement in winter conditions is carried out under intensified technical control. Usually the work is separated into three stages: a) constant or daily control of observation of all technological requirements of the execution of road-construction tasks in winter conditions; b) interim approval of finished sections immediately after their completion; c) a second and final approval of all work completed in the winter period, after full thawing of the graded bedding

and the construction of the road surface and execution of all the final finishing work.

Approval of the work accomplished in the winter is carried out in full compliance to the existing rules and standards without any allowances made for the special nature of the work.

AD-A035 906 COLD REGIONS RESEARCH AND ENGINEERING LAB HANOVER N H F/G 13/2
PREFABRICATED HIGHWAY PAVEMENTS (SBORNYE POKRYTIIA AVTOMOBIL'NY--ETC(U)
JAN 77 V M MOGILEVICH, E N DUBROVIN
UNCLASSIFIED CRREL-TL-577 NL

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CHAPTER VI

PARTICULARS IN THE EMPLOYMENT OF PRE-FAB CONSTRUCTIONS IN THE BUILDING OF CITY ROADS

28. Particulars in the Employment of Pre-fab Coverings on City Roads

In cities, road pavements with asphalt coverings have received the widest use. However such coverings, in most cases, do not possess the necessary stability and longevity on main roads with concentrated traffic, heavy truck and public passenger transport. In the process of putting the roads into service, there appear shifts, cracks, pot holes and other defects. This leads to the necessity of allotting vast expenditures in repair work, the execution of which is very complicated in heavy traffic. Therefore, the important task at hand is to raise the quality and lengthen the life of road pavements with the simultaneoud reduction in their cost.

One of the most feasible ways of trying to solve this problem is to employ cement and pre-stressed concrete constructions, the life of which is estimated in decades.

Until recently, cement and pre-stressed concrete road pavements were used mostly in the form of monolith slabs. The limited use of segmented constructions of road pavements made from pre-stressed concrete is explained by the fact that there was an absence of an industrual base for their production. In recent years in cities of the USSR a wide network of factories producing pre-stressed concrete has been built. These factories are equipped with modern technology which has created the favorable conditions for the broadening of the use of pre-fab, pre-stressed concrete in the construction of pavement on city roads.

Earlier in this text it was shown that pre-fab coverings have basic advantages over monolith construction. In building cement-concrete coverings and foundations in city conditions, these advantages are seen even more boldly. Interruption of traffic because of road-construction work should not last more than a few hours. On the other hand, building monolith cement-concrete coverings usually necessitates the closing of traffic along the freshly laid concrete for periods of 7-15 days and more (For a concrete construction of sufficient strength).

Construction of monolith cement-concrete road pavement is associated with a concentration of cumbersome equipment and a significant number of workers.

Monolith cement-concrete road pavements in specific circumstances of construction of city streets have other shortcomings: complicated, old sections of the city are full of underground communications. For their repair it is often necessary to remove the road pavement. Cement-concrete monolith coverings are difficult to take up and even more difficult to replace in order to receive their previous strenght. To construct a monolith, pre-stressed covering is practically impossible; therefore the pre-fab type in the given example has a irrefutible advantage. When they are constructed with slabs connected with couplings, they can be easily taken up and replaced.

On the construction of slabs and joining connections depends not only the technology of the assembly of pre-fab coverings, but also its high operational qualities, which can be ensured if the covering has the required strength, eveness and endurance. It is well know that slabs of small dimensions and complex construction are not only labor-consuming in their porduction and assembly, but also lower the operational qualities of road pavements. Forming in the covering a large quantity of seams and joints, they create inconveniences for the movement of traffic and serve as a cause for surface moisture to reach the foundation (this hastens the deterioration of a pre-fab construction).

The most reasonable construction for city roads is the large-sized, reinforced concrete slabs which have a rectangular shape. The width of such slabs should be equal to the width of a lane of traffic, that is, 3.0; 3.5; 3.75 m., and a length of 5-7 m. and more. Enlargement of the dimensions of the slabs allows the possibility to use more fully the equipment which produces the slabs, raise the productivity of labor when assembling them, and at the expense of reducing the number of joints, to raise the level of operational qualities of pre-fab coverings.

In recent years, scientific institutes and development institutes, which specialize in the building of city roads, together with the industrial organizations fo road management, have brought into operation a series of new pre-fab constructions of road coverings. Credit is given to them for the development of pre-stressed reinforced concrete road slabs which have come into service in city road-construction.

It is recommended to employ coverings of such types of slabs on the trunk roads of cities with concentrated automobile traffic. Slabs of smaller dimensions (rectangular, square, hexangonal) are best used on thoroughfares w... little traffic, parking lots, park paths, etd.

The most important requirement is maximal evenness of a pre-fab road covering, which must last for a long period of time.

Unevenness of the pre-fab covering in several instances can be explained by the insufficient strength of the foundation. The graded bedding under city streets is composed, in the main,

of various types of land fill. Therefore, in the erection of pre-fab coverings careful attention must be given to the quality of the graded bedding. Unsuitable earth must be taken away, places where public service communications have been laid, and various excavations must be filled in layers with draining soil and carefully packed. In a number of cases it is necessary to place a layer of sand-earth foundation, secured with cement.

Another cause for the formation of uneven pre-fab coverings is the out-dated construction of joint connections. Joints of pre-fab coverings, made of large-sized pre-stressed reinforced concrete slabs, should possess the strength and rigidity close to the strength and rigidity of the mean cross-section of the slabs themselves. This allows the possibility of creating out of pre-fab units a jointless covering of significant length and width and which approaches the type of work in a monolith, pre-stressed, seamless covering.

Along with the required strength and rigidity, joints for pre-fab coverings on trunk roads should be water-impermeable. Water-impermeability of pre-fab coverings can be ensured by the treating of joints with a variety of grouts.

The most suitable grouts are those which are prepared from expanding, quickdrying cements and synthetic glues. With the aif of effective glueing compounds, it is possible not only to fill in the seams, but also to glue the joints of pre-fab covering units. This will permit builders to avoid the application of expensive metals and to simplify the assembly of joints.

Pre-fab coverings should be water-impervious even in the gutter portions. Surface run-off of rain, melting snow, hosing of streets usually take place to the side of the traversed part of the road, collects in the gutters, which take it to the storm drains of the sewer system. With roads of large longitudinal slopes, considerable speed of flow is created and the water can wash away and destroy the pre-fab covering. And with minimal slopes, water can collect and be held, penetrating to the foundation of the road pavement instead of running off to the side. With the goal of eliminating this defect, pre-fab coverings of large dimension, pre-stressed reinforced concrete slabs are arranged in combination with the side. Such slabs for the gutter sections of the street are developed by the All-Union Correspondence Instutute for Engineers and Builders (construction is described in chapter I). Combination of slabs with the side allows for the water-impermeability of the pre-fab covering in the gutter sections.

Another variation of this problem is the securing of large-sized concrete side-blocks to the surface of the water-impervious gutter-slabs of the pre-fab covering.

The presence of frequent cross-streets on city roads, public transportation stops, pedestrian crossings, etc. has more and more brought out the requirement

which can ensure the shortest breaking time for motor vehicles and guard against skidding of traffic into adjacent lanes. Therefore, when making slabs for pre-fab coverings of trunk streets, a scored surface on the working side of the slabs should be created.

With the goal of ensuring traffic safety on city streets, it is advisable to make the slabs with various surface painting. Such slabs can be paved places for pedestrian crossing, parking, safety aisles, dividing lanes, etc.

In the case of the placing of public servide-communications under the pre-fab coverings, the necessity to include in the coverings storm-drain hatches, and other service shafts arises. This point is one drawback to the employment of pre-fab coverings, because for each instance of such a hatch, etc., an individual slab must be made at the factory or treated at the construction site.

29. PRE-FAB CONSTRUCTION OF DRAINAGE SYSTEMS

The quality of city road surfaces of any construction, to a large extent, depends on the appropriate drain-off of surface water from the street bed. The handling of surface-water drain-off (rain, melted snow, water from hosing and washing of streets) and the lowering of the level of ground water (where necessary) is an essential and inseparable part of the design of city streets, roads and squares. With the construction of improved road surfaces in the city, water-drainage from the surface of the road and its adjacent areas represents part of a closed network of water drainage systems.

The closed system of water drainage consists of the following elements:

1) gutters of city streets, roads, squares;

2) water-receiving (rain-receiving) storm drains, into which run the water from the surface gutters;

3) underground connectiong conduits (branch lines) from the storm drains to the street sewers;

4) closed network of street pipelines, which consist of drains and collecting mains;

5) special installations: barrels for various purposes (merging, snow reception, flux), siphons, cleaning equipment, etc.

The principle units of the drain network are: storm drains and service shafts, round conduits with a cross section of 0.3 to 3.5 m., pre-fab collecting mains with a rectangular cross-section 1.2 x 4.0 - 1.8 x 3.0 m. and special installations.

All units for the water-drainage system are now being made in factories from pre-fab, concrete and reinforced concrete constructions.

Storm sewers with a diameter up to 0.6 m. are built with non-ramming concrete conduit 1.0-1.5 m. in length. Joints are made with a bell-mouth conduit, in a quarter and with straight plane. The bell-mouth is finished for one third of the depth with a resin lock, then filled in with a cement or asphalt mastic. Joining the conduits into a quarter is done with a cement grout or asphalt mastic. The conduits with straight planes are connected with the aid of couplings or treated with a concrete grout.

Round, non-ramming reinforced concrete conduit, put out by industry, can be separated into small - by diameter of 0.3-0.6 m.; average - 0.7-1.0m; large - 1.2-3.5 m.

Depending on the form of joints, reinforced concrete conduits are separated into bell-mouth stepped or beveled, grooved and smooth sloped. (Fig.141.)

Preferance is given to conduits of the bell-mouth and grooved types, because conduits of the smooth plane type have to be joined by reinforced concrete couplings or concrete fitting bands. Bell-mouthes of reinforced concrete conduits are finished with a lock of resined hemp rolled into bunches, or resined rope, and caulked with the help of a pneumatic hammer. A bell-mouth is finished with an asbestos-cement mixture from the outside of the conduit in layers of a thickness no larger than 2 cm. Seams on a reinforced concrete conduit of the larger diameters are finished from the interior with a cement grout with water-soluable glass.

The most perfect means of finishing joints is the application of plastic, water-impervious tape, made on a bitumen base, which is glued to the bell-mouth part or the interior part of the grooved conduit. When the smooth sloped conduit is placed into the bell-mouth, or the comb into the slot of a grooved conduit, the plastic material is pressed and hermetically seals the gap between the ends.

Reinforced concrete conduits are classified by conduits of normal strength, calculated for a height of flow up to 4 m. (under a stress H-30 and HK-80), and increased strength, calculated for a height of flow over the conduit of more than 4 m. (under a stress H-30 and HK-80). Conduits of normal and increased strength are distinguished by their wall thickness. However, with the proper technology it is completely possible to make conduits of the same diameter in the same molds with one wall thickness, applying a stronger reinforcement for the conduits of increased strength.

The thickness of the protective layer for reinforced conduits is regulated both for the interior and the exterior sides and should be no less than the magnitude indicated in table 39.

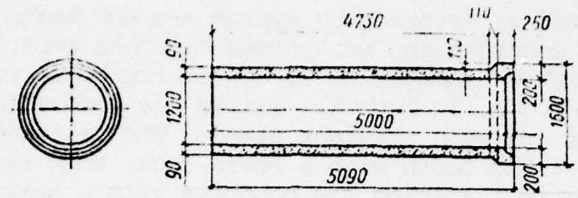


FIG. 139. Bell mouth reinforced concrete conduit

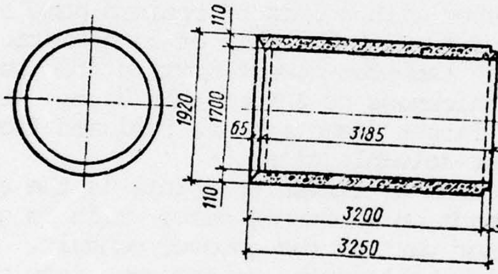


FIG. 140. Reinforced concrete conduit with a juncture in a "quarter"

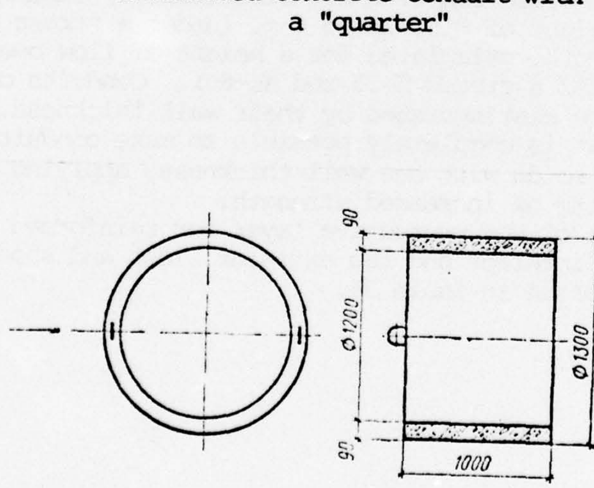


FIG. 141. Reinforced concrete conduit with smooth planes

Concrete and reinforced concrete conduits are made from concrete on no lower mark than 300. The doncrete is prepared with two-three fractional crushed stone or gravel of strong stone type; cement of mark 500 is employed. Water absorption of the concrete conduit should not be more than 6%, a mark of concrete conduit by frost-resistance no less than Mrz-50.

TABLE 37

Diameter of passage mm	smallest thickess of conduit wall, mm	smallest thickness of conduit mm	form of bellmouth
300	50	5000	stepped or conical
400	50	5000	
500	60	5000	
600	60	5000	
700	70	5000	
800	80	5000	
900	90	5000	
1000	100	5000	
1200	110	4000	
1500	110	4000	
1750	110	3500	
2000	130	2500	
2500	150	2500	

TABLE 38

diametwer of passage	thickness of wall	smallest length of conduit wall, mm
1750	110	3500
2000	130	2500
2500	150	2000

TABLE 39

diameter of of conduit	interior side	exterior side
300—500	15	—
600—1000	20	—
1200—1750	25	20
2000—2500	30	20

Wall thickness of the reinforced concrete conduit usually comes to about 1/10-1/12 of the interior diameter.

In recent years, constructions of thin-walled bell-mouth and grooved reinforced conduits of a diameter 1.5-3.5 m. and a wall thickness up to 1/20 of the interior diameter (which allows for considerable reduction of the volume of reinforced concrete used) have been developed and tested.

Such conduits are produced in the Moscow factories of the Principle Moscow Industry for Building Materials.

In Table 40, the technical and economic indicators for reinforced conduit, produce by the Moscow factories, are listed.

TABLE 40

conduit grade	interior diameter mm	wall thickness mm	lengths of link	length of link	vol. of cond.	weight of conduit
PT-15	1500	90	4,09	1,96	130	4,9
PT-15y	1500	90	4,09	1,96	161,6	4,9
PT-17	1700	110	3,10	2,08	111,5	5,2
PT-20	2000	110	2,80	2,21	122,0	5,53
PT-25	2500	120	1,82	1,85	143,5	4,63
ЧТ-17y ЧТ-17	1700	110	3,25	1,99	149,0	4,98
ЧТ-20y ЧТ-20	2000	130	2,35	1,99	127,0	4,98
ЧТ-25y ЧТ-25	2500	150	1,88	2,15	109,0	5,37
ЧТ-30y ЧТ-30	3000	160	2,50	3,83	154,0	9,58
ЧТ-35y ЧТ-35	3500	180	1,90	3,72	137,5	9,30

LEGEND: PT - conduit with bell-mouth coupling of normal strength; T - conduit with coupling in quarter (grooved) of normal strength; y - strengthened conduit of increased strength; 25 - diameter of a conduit 2500 mm.

The conduits put out by the factories should maintain a constant, cylindrical shape throughout their length. Their walls should not have transverse or longitudinal fissures. Quality control of the reinforced concrete conduits is made by testing for water-impermeability, strength and fissure-resistance. Testing for water-impermeability can be accomplished by two means: a) filling the conduit with water, the conduit having been placed in a vertical position. Measurement of the run-off is by the amount of reduction in the water level in the course of 3 days; b) filling the conduit with water under pressure and measurement of the loss of water after 15 min.

The conduits pass the test for hydraulic stress if on their surfaces no seepage in the form of drops reaches the outside of conduit.

To test the conduits for fissure-resistance and strength, only conduits which have passed the test for water-impermeability are used. In this test, pressure from a jack, placed in the middle of the conduit, is uniformly distributed along the upper formation the entire length of the conduit with metal traverses and wooden bars, 10 x 10 cm. Depending on their diameter, high-quality conduits should withstand the minimal stresses P, listed in Table 41 in agreement with GOST-63, "Reinforced Conduits and Concrete Non-Ramming Conduits."

TABLE 41

diameter of passage D y mm	destructive stress P, kg/m of conduit		
	concrete	reinforced concrete	
		normal strength	increased strength
200	1500	—	—
300	2000	2600	3000
400	2500	2850	3500
500	3000	3100	4000
600	3500	3450	4500
700	—	3900	5200
800	—	4350	5900
900	—	4800	6600
1000	—	5250	7300
1200	—	6150	8700
1500	—	7500	10 800
1750	—	В зависимости от конкретных условий строительства и эксплуатации трубопровода	
2000	—		
2500	—		

Under pressure consisting of 55% of that necessary to destroy the conduit, the magnitude of the fissure on the surface of the wall in reinforced concrete conduits should not exceed 0.2 mm. A destructive stress is one that results in one of the following conditions: rupture in the reinforcement, separation of the reinforcement in the crown or the trough of the conduit, destruction of the concrete in the pressured area, opening of a fissure larger than 1.5 mm. To check the compactness of the coduit concrete, checked for mechanical strength, three smaples are torn from the wall for the entire thickness of the wall. They are tested for water-absorption, which should not be more than 6% of the weight of the concrete, dried out to its constant weight.

Along with the use of round collecting mains with a diameter of reinforced concrete conduits and rings more than 1.5m., pre-fab constructions of rectangular cross section are used. The collecting mains of closed, rectangular cross section consist of walled blocks of a gamma-shaped form, flat slabs for the bottom and ribbed slabs for the covering.

Walled blocks, used for gravity channels, have exterior ribs with finished slabs, the thickness of 9 cm. Horizontal slabs of the blocks have 4 kinked reinforcement-escapes each, with which they unite with the slabs of the bottom. Blocks of the overhead cover also have exterior ribs with a thickness of 9 cm.; they jut out from the body of the slab.

Before installing the walled blocks for concrete preparation, a layer of water-isolator is placed on the bitumen and a glue hydroisolation is done on the exterior, vertical borders of the walled blocks, 0.5 m higher than the preparation. After installment of the walled blocks and the laying of the bottom block and cover, the collecting main and all elements are waterproofed and, work like a frame which had

hinged joints on the top of the walls. The upper part of the exterior walled blocks is covered twice with a hot bitumen, and the blocks of the cover are covered twice with layers of glue hydroisolations and then on top of that, one layer of molten or sand asphalt-concrete. The foundations for pre-fab collecting mains are arranged in a fashion dependent on the earth and hydro-geological conditions.

In the case of the use of reinforced concrete slabs for the foundations, the former are accepted with a thickness of 10 cm. with a mounting-reinforcement. The width of such slabs is applied to the short length of the walled block, and, as a rule, one slab should lie under the joint of another walled block.

In Table 42 is listed the specifications for the pre-fab gravity channels, and in Fig. 142 a, b, c, is shown the design for the pre-fab reinforced concrete construction.

TABLE 42

grade of concrete	dimensions in cm			vol. of concrete m^3	weight T
	H	B	C		
wall blocks					
ДС-3К	199	180	20	0,77	1,92
ДС-4К	229	180	20	0,84	2,10
ДС-5К	259	180	20	0,91	2,28
ДС-7К	319	180	20	1,07	2,68
bottom blocks					
ДО-4	70	180	14	0,18	0,45
ДО-5	90	180	14	0,23	0,58
ДО-6	110	180	14	0,28	0,70
ДО-7	130	180	14	0,33	0,83
ДО-8	150	180	14	0,38	0,95
ДО-11	210	180	16	0,61	1,52
ДО-13	260	180	18	0,84	2,10
cover blocks					
ДП-1К	130	180	20	0,31	0,78
ДП-3К	170	180	20	0,41	1,03
ДП-4К	190	180	20	0,46	1,15
ДП-6К	230	180	30	0,65	1,63
ДП-7К	250	180	30	0,70	1,70
ДП-8К	270	180	30	0,76	1,90
ДП-9К	300	180	32	0,87	2.20
ДП-11К	350	90	32	0,64	1,60
ДП-13К	400	90	32	0,73	1,83

Inspection and storm-drain wells are arranged, on the whole, with pre-fab reinforced concrete units. The inspection well consists of a working chamber and a neck above it, which serves to lower people into the well. The working chamber, at a height of about 1.8 m. is made in a round, square or rectangular shape (depending on the diameter

of the conduits and the material of the well). The neck of the well is made from reinforced concrete rings with an interior diameter of 0.7 m. The height of the neck depends on the depth of the well. The minimal interior diameter of the working chamber of the inspection well is 1.0 m for conduits of a diameter 0.5 m. For conduits with a diameter more than 0.5 m, working chambers are 1.2-1.5 meters in height.

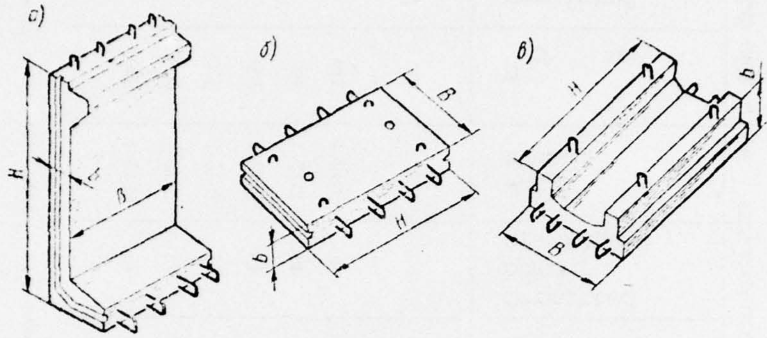


FIG. 142. Units of pre-fab storm-drain collecting mains (a, b, c)

Round wells of pre-fab construction consist of a slab for the bottom, rings for the working chamber, a slab for the cover of the working chamber, rings for the neck, and a supporting ring on which the hatch is placed. In Fig. 143 the pre-fab reinforced concrete inspection well in storm-drain systems, made from conduits with a diameter of 300-700 mm, is represented.

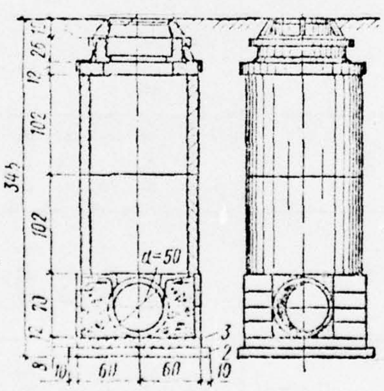


Fig. 143. Pre-fab reinforced concrete inspection well: a - cross section; b - general view; 1 - hydroisolator; 2 - sand pad; 3 - concrete pad.

Four types of inspection wells are manufactured: for installment on a linear pad of conduits, for a turning pad, with one and two connections. In fig. 144 are represented the designs for inspection wells in storm systems.

At the present, factories are assembling units for inspection and storm-drain wells. Consolidation of the units into one construction significantly improves the transportability of the product and shortens the loss of labor hours in the assembly of the wells at the building site.

TABLE 43

ТАБЛИЦА 4

interior diameter D_y mm	linear well type	turning type 15°	turning type 25°	turning type 35°	turning type 45°	with one connection: well type	with one connection: D_o mm.	with one connection: permitted number of troughs	with two connections: well type	with two connections: D_o mm	with two connections: permitted number of troughs
300	B-10-2	B-10-2	B-10-2	B-10-2	B-12-2	—	—	—	—	—	—
400	B-10-2	B-10-2	B-10-2	B-12-2	B-15-2	B-12-3	300	—	—	—	—
500	B-10-2	B-10-2	B-12-2	B-15-2	—	B-12-3	300	—	B-12-4	300	—
600	B-12-2	B-12-2	B-15-2	—	—	B-12-3	300	40	B-12-4	300	40
700	B-12-2	B-12-2	B-15-2	—	—	B-12-3	300	40	B-12-4	300	40
800	B-15-2	B-15-2	—	—	—	B-15-3	300	75	B-15-4	300	75
900	B-15-2	B-15-2	—	—	—	B-15-3	300	75	B-15-4	300	75
1000	B-15-2	B-15-2	—	—	—	B-15-3	300	75	B-15-4	300	75

Примечание. В марке колодца первая цифра, стоящая после буквы «В», обозначает внутренний диаметр колодца в дециметрах, вторая — количество отверстий в цилиндре рабочей камеры

Construction of storm-drain wells can consist of separate units: cone, rings, and bottom or a whole reinforced concrete well, assembled at the factory by welding the separate parts together. In Fig. 145 is shown the pre-fab storm-drain well.

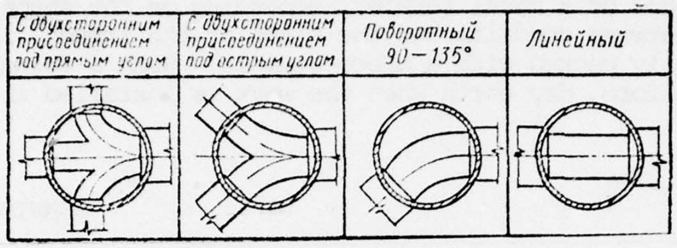


Fig. 144. Principle means of inspection-well application

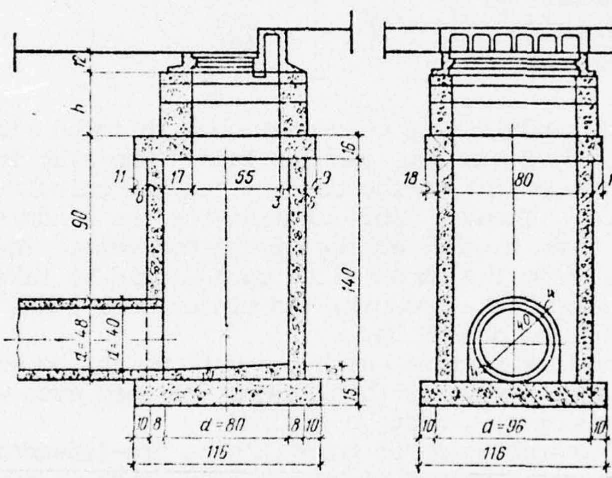


Fig. 145. Pre-fab, reinforced concrete, storm-drain application

The height of the well, from the trough to the top of the construction, is 1.55 m. The depth is increased to .70 m. with the addition of the hatch and screen. The weight of the well is 1 - 1.2 tons.

Chambers that are rectangular in plan are arranged on conduits of large diameter for complex joints, furnishings not added in round wells. Such chambers are built according to individual projects. But in all cases, the height of the filling above the cover of the working chamber of well, up to the surface of the land, is dictated by the calculation of the vertical lay-out of the locality and should not be less than 0.5 m.

Selection of the foundation for the sewer conduit system is made for each spedific situation depending on the giological, hydrogeological conditions of the location, the dimensions and construction-type of the conduits.

In the case of installation on natural earth foundations, a trough is formed from packed sand with padding under the conduit. The torugh is carefully planed by means of a metal templet, depending on the shape of the conduit. The fill, between conduits and the slant of the trench, is made from sand-earth, carefully packed with a bibro-stamper. Such a foundation is recommended for uniform, dry earth when the work is installed in summer and fall conditions.

DRAWING 44

indeces	Block BO-3	Block BO-4
weight, T	3,2	1,56
volume, m^3	1,33	0,65
weight of metal, kg	62,0	63,0
outlay of metal/m^3	47,0	97,0
grade of concrete	200	200

Installation of conduit on a concrete-monolith foundation is carried out in two parts: first, a concrete slab is laid. The slab is chosen to meet the demands of the weight of the conduit and the calculated deformation of the earth base. Then, a table is made for the conduit with careful attention being given to the packing of the concrete. The pockets are filled with the earth from the local site; care should be taken so that there are no empty spaces around the conduit. In winter, only thawed earth is used and any clods must be broken up.

Concrete foundations replace earth foundations in the winter construction of conduit systems. Concrete foundations are used even when a good padding (under the conduits) cannot be ensured.

In the case of installation of conduit on a pre-fab-monolith foundation, prepared reinforced concrete slabs are laid, then, a monolith, concrete block is made for under the conduits. A foundation of this type can be recommended only for work in winter and in those cases when, because of the technology, there is not enough time between the installation of the conduit and the laying of the foundation.

Pre-fab reinforced concrete foundations and their combination with the conduits by means of a cement-sand grout are used for weak earth or in the construction of an artificial foundation under the conduits.

For conduits of large diameters, factories put out pre-fab, reinforced concrete blocks BO-3 and BO-4 (Tables 44 and 45).

Table 45

Name of Block	No.	Metal Specification			
		Component Part Brand	Number of Component Parts	Weight, Kg.	
				Of component Parts	Of the Articles
Base block BO-3	1	S-1	1	27,87	27,87
	2	S-2	1	18.75	18,75
	3	Individual rods			14,31
	4	Binding wires			1,07
		TOTAL			62,0
Base block BO-4	1	S-1	2	21,32	42,64
	2	Individual rods	2		19,39
	3	Binding wires			0,91
		TOTAL			63,00

30. Pre-fab Units for Streetcar Tracks

On city roads tram-ways can be laid either on the same level as the traversed portion of the street or on a special bedding. In the first case, the zone of tram tracks is also used by the railless public transport, and, therefore, the covering of the tramway must have the same qualities of the street pavement of the traversed portion of the road (that is, it must be strong, stable and differ little in its appearance from the surface of the traversed part of the road). The covering of the tramway, placed on a special bedding, is not meant for railless, public transport, and serves to protect the tramway from surface water. Such a bedding also allows the passabe of repair machinery necessary for the upkeep of the tramway and its contact network.

The main stress from the rolling stock is carried by the foundation, which should ensure strength, firmness, longevity of both the foundation itself and the surface covering. It must be rigid and, at the same time, elastic to a certain degree in order to increase the endurance or the rails, lessen the shock and reduce the noise which arises with the movement of the cars.

At the present, ther exist several different types of pre-fab, reinforced concrete foundations for underneath the trackbed. They differ by construction: Geometric forms, types of interval rail fastenings, means of reinforcement, grade of concrete, etc. If you take the characterizing peculiarities of road work as a basis for construction types (that is, rails, trackbed foundation, tramway and road pavement under stress),

then it is more expedient to classify trackbed foundations under the following headings: the first heading -- foundations of the uninterrupted (ribbon) type, joined with the tramway road pavement; the second heading -- foundations of the uninterrupted (ribbon) type, working separately from the tramway road pavement.

Under the first and second headings there can be made two structural differentiations -- with separate and non-separate attachment of rails to the track-bed foundation. These two differentiations can have an influence on the working of the road under stresses.

In the first group of combined track-bed foundations there are two types of constructions: Slab footing and block foundations. Both types of combined foundations have separate attachment of rails.

In the second group there are several types of foundations: frame ties (constructions of the Scientific-investigatory Section and Service of Roads in the Administration of Passenger Transportation of the Executive Committee of Moscow), Frame-panel ties, flexible frame types and single footing types, etc.

An inseparable part of modern railway construction is industrial types of road pavements made of pre-fab reinforced-concrete. Pavements for tramways also can be devided into two groups: slabs, which rest on the flattened, intermediary layer of ballast and work separately from the foundations of the tramway bed; and slabs combined with the track bed foundation.

Pre-fab, reinforced-concrete, track-bed foundations and roadway pavements are dependent on structural differences and can be made from normal or pre-stressed reinforced concrete.

Since track-bed foundations and tramway pavements are located in complex situations and, in the process of operation experience, considerable, dynamic stresses from the moving tram and railless traffic, special requirements pertain to the concrete of these constructions. This is in addition to the general requirements which shoudl be satisfied by reinforced concrete constructions which must operate in the open air.

The concrete should have limited shrinkage and creepage and a raised level of water impermeability and frost-resistance.

For the making of railway-construction units for the streetcar, heavy concrete (with a unit weight of 1,800 kg/m^2 and more) of grades 300, 400, and 500 are used.

The grade of concrete for constructions made from pre-stressed, reinforced concrete is chosen by consideration fo the means of anchoring the reinforcement and further determined by technical economic considerations. For constructions in which locks (in view of reinforcement) made from round, cold-drawn wire or

single wires, which are treated (cut notches, grading lines, pickled surface), are used, the grade of the concrete should not be lower than 400. When wire of a periodic profile with a diameter of 5 mm and less, smooth wire with anchors, is used, the grade of concrete should be no less than 300. Concrete of this grade is used also in combination with reinforcement with a periodic profile, made from hot rolled bars the diameter of more than 20 mm and cold-flattened wire with a diameter of more than 14 mm. The most effective use of concrete of high grades is combination with the optimal form of thin-walled units in cross section. With this grade of concrete, the outlay of filling and cement is less than with concrete of lower grades.

The requirements for the concrete are conditioned by the general structural considerations. In many cases deviations from the indicated grades, based on test results, are possible.

Usually the transfer of stress to the concrete is made before the concrete has reached thestrength of its grade. It is very important that the strength of the concrete, at the momemt the stress is transfered to it, ensures the anchoring of the reinforcement.

Creeping increases when the stressing of the concrete exceeds the 50% of the cubic strength that leads to increased losses of the pre-stress. Coming out of these considerations, the following indications of the smallest cubic strength of concrete under stress are acceptable: When using cold drawn wire the diameter of 2.5-5 mm, the figure is 200 kg/cm^2; 6 mm and more -- 300 kg/cm^2; hot rolled steel of periodic profile -- 200 kg/cm2.

FRAME TIES: Frame ties are a transitional type of track bed foundation between whole-bar, single tie construction and pre-fab, reinforced concrete railway construction.

At first frame ties were suggested for railway construction, but for a number fo reasons they did not receive widespread use on railway transport(the special character of railway work, packing of sleepers with machines, smoothing out of the road, etc.). However, given the conditions of work on tramways, frame ties have an advantage over single ties; therefore, the first examples of frame ties, laid on tramways, were ties of the railway type, made from prestressed, reinforced concrete, produced as a project of the TsNIIPS.

The frame tie is a closed, straight-side quadralateral with a length of 1700 mm, width of 1950 mm and with two footing parts, on which are laid rails, and two transverse members, which ensure stability of the track (Drawing 146). The thickness of the ties is 160 mm. The attachment of the rails is non-separated, with spikes or wood acrews in oak doweling. The frame tie is reinforced with cord made of high-strength steel wire

with a diameter of 3 mm, distributed in five vertical rows.

Uninterrupted reinforcement is realized on slewing tables. Several frame ties of this type were laid on a tramway for experimental operation. It became clear that the railway frame ties have an excess reserve of strength and can be modified.

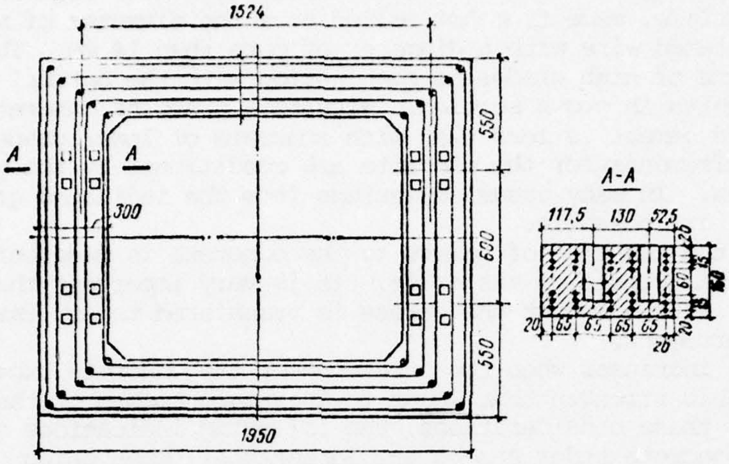
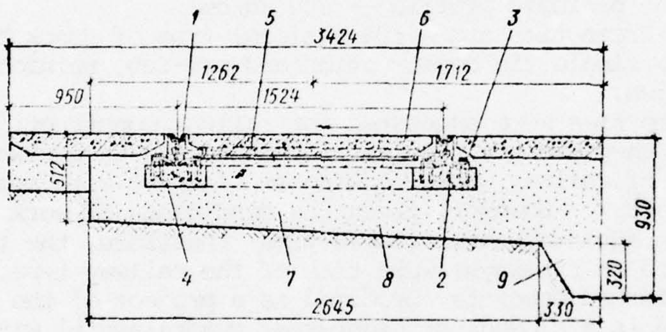


Fig. 146. A Railway Frame Tie.

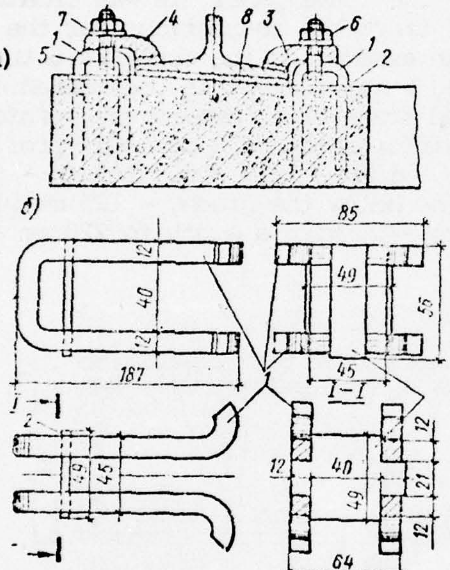


Drawing 147. Construction of a tramway on railway frame ties: 1 - rails; 2 - rubber padding; 3 - clamping; 4 - frame ties; 5 - flat thrust; 6 - reinforced concrete slabs; 7 - sand; 8 - road trough; 9 - drainage.

Also advisable is the change of the construction for clamping the tie to the rail.

of the construction for clamping the tie to the rail. Considering these conditions, a frame tie especialy for tramways was developed.

The Administration of Passenger Transport for the Moscow Executive Committee developed a construction for the frame ties (of reinforced concrete) to be used on roads with ordinary reinforcement (Drawing 147). It is recommended to use this construction on straight and curved stretches of road with a radius greater than 100 m when the longitudinal slope is no more than 40o/oo and no more than 20 trams per hour. If there is traffic of more than 40 trams per hour, hte sand-ballast base can be replaced with crushed stone construction. The longitudinal slope of the road, in this case, should not be more than 60o/oo. Temperature compensators are installed every 400 m. Rails rest on the ties with a rubber padding the thickness of 8 mm. Reinforced-concrete slabs 13 cm thick are used as a pavement.



Drawing 148. Rail clamping on frame ties: a- general view; b- anchor clamp with plate; 1- anchor clamp; 2- coupling plate; 3- boss, internal-clamping; 4- boss, external-clamping; 5- special bolt; 6- nut; 7- washer, clamping; 8- padding.

Between the rail footing and the the concrete is placed a rubber ribbon the width of 180 mm, thickness of 8 mm. The rails are attached to the ties with anchors, which consist of two clamps of a square cross section (12 X 12 mm), joined by an iron plate (thickness -- 5 mm), welded to the clamps (Fig. 148). The clamps are finished into the concrete to the level of the upper plane of the plate. The head of the bolt, which is fastened with a turn of the bolt of 90°, goes into the upper part of the anchor. On the bolt is fitted a boss, which rests as a sponge through the rubber padding on the upper edge of the rail footing, and as a shank on the horizontal shelf of the anchor. By means of a boss, spring-actualed washer and a nut, the rail is clamped to the tie.

In Table 46 are given the technical characteristics of the frame tie.

TABLE 46

Dimensions of Frame Cross Tie			Weight, Kg.	Concrete Brand	Expenditure of Reinforcements, Kg.	Dimension of the Window	
Length	Width	Height				Length	Width
175	194	130	150	300	185	120	120

FRAME-PANEL TIES. At the suggestions of S. A. Lyzov, as a variation of the frame tie, the frame-panel tie was developed. It is the joining of several ties into one unit (fig. 149). The frame-panel tie was created with the goal of enlarging the units of track-bed foundations for the abbreviation of the operations involved in assembling the supperstructure and foundation fo tramways. Prestressed reinforcement is considered only in longitudinal, track-bed footings, and transverse members are reinforced without prestressed bars by means of reinforcement of a periodic profile. Overall dimensions of frame-panel ties: width - 1912 m.m.; length - 6220 m.m.; average height of footing parts, measured below the grade, - 125 mm with the width of 340 mm; number of cross members - 5, with a width fo 220 mm and height of 95 mm.

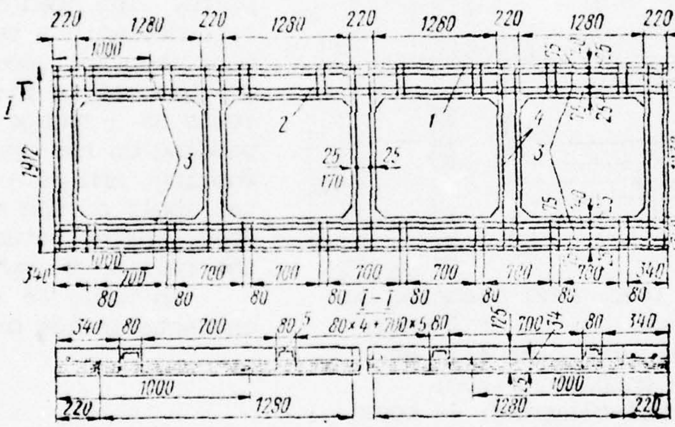


Fig. 149. FRAME-PANEL TIE:
1 - longitudinal reinforcement; 2 clamp; 3 - hiosting loop; 4 - reinforcement of cross beams; 5 - anchor case.

The reinforcement of longitudinal footing parts can be accomplished either with cord of a 3 mm diameter, distributed in four vertical rows, or with cord of a 2.5 mm diameter, distributed in six vertical rows. Ultimate resistance of the reinforcement wire, in both cases, is 17000 kg/cm^2,

control stress of the prestress of the reinforcement is 11000 kg/cm^2, grade of concrete is 500. The weight of one frame-panel tie is 1.5 tons. Fastening of the anchor case to the rails consists of an angle No. 90 x 60 tons and the head of the bolt. The anchor case consists of an anchor case, formed with a section of channel No. 8 and a slot for the shank of the hoisting goss. The hoisting boss fits into the slot of the anchor case by means of its shank, which excludes the possibility of its being turned in relation to the case. In the same slot fits the head of the bolt; by means of a 90 degree turn, it is secured to the box. Along with a washer, a hoisting boss is fastened to the footing of the rail. Under the rail, for the entire length, is laid a rubber padding with a thickness of 8 mm.

Frame-panel ties are laid 160 units per 1 km of single track. Frame and frame-panel ties can be laid on sand or crushed stone ballast when unit road pavements (stone blocks, reinforced-concrete slabs) are used, on both separate road beds and on the traversed part of the street. It is still preferred to lay frame ties on a separate bedding, because they are especially elastic and do not work well in conjunction with the pavement of the street (with the exception of joined reinforced-concrete slabs) under the stress of automobile traffic.

FLEXIBLE SLEEPER FOOTING: Track bed foundations for flexible units (frame and single longitudinal sleeper footings) differ in their operation from all other types of foundations. This is due to the fact that, because of their lack of rigidity, they are load bearing units and serve as interval units which distribute the stress from the rails to the ballast. The footing is raised by the ballast's reaction pressure to the rails, and its camber is full coincident to the camber of the rail. Thanks to the elastic padding, friction between the rails and the footing allows such insignificant displacement that this factor is hardly worthy of consideration.

For all varieties of sleeper footings, a minimal height of 60-70 mm is employed; the fact of which allows this type of track bedding a significant reduction of weight and volume of reinforced concrete per unit of track. The construction of flexible sleeper footings was suggested by candidates of technical sciences Ye. V. Ovechnikov and I. M. Kotelikov.

Flexible, prestressed frame sleeper footing for tramways is a closed rectangular frame (fig. 150) with dimensions on its outer contour: length 2880 mm, width 1904 mm. The track bed footings are long units of frame, which have a width of 380 mm and a variable height of 58-68 mm. A transverse unit of frame has rectangular cross sections 160 x 58 mm and serves in the capacity of a transverse member between two footings. The sleeper footing is reinforced with prestressed, high strength wire by means of wrapping it from a slewing table on a pin pallet. The high strength wire is wrapped on strong anchor rings, which are left in the body of the concrete.

Besides the uninterrupted prestressed wire, sleeper footing is reinforced by two welded grids made of

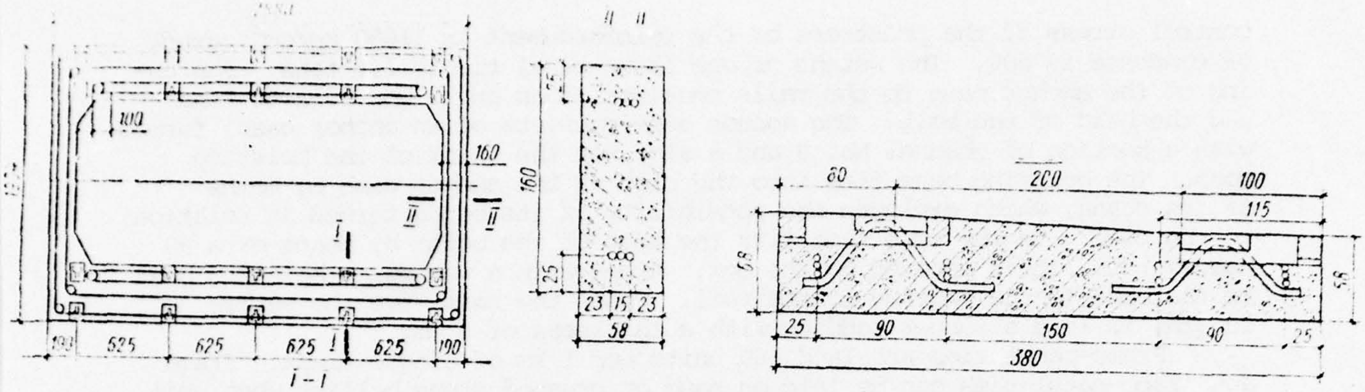


Fig. 150. Flexible Frame Footing

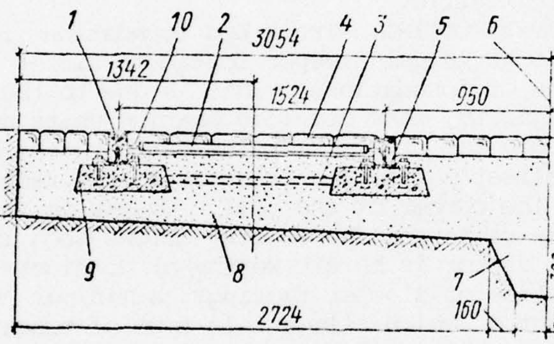


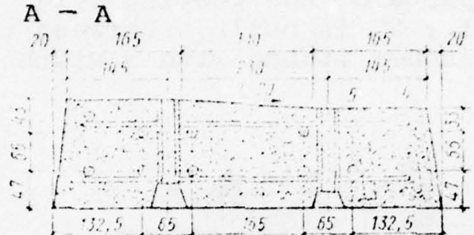
Fig. 151. Streetcar Reinforced Concrete Footing:

1-Rail; 2-Flat thrust; 3-Thrust which clamps the footing; 4-Stone blocks; 5-Plastic padding; 6-Track spacing axis; 7-Drainage; 8-Ballast layer; 9-Reinforced concrete footing; 10-Beam.

cold-flattened wire diameter of 6 mm or hot-rolled, profiled steel, grade 25G20.

For fastening the rail to the sleeper-footing, on the latter are placed anchor cases with sockets for the bolt head. The rail is laid on the footing the entire lower surface of its flange. Between the footing and the flange of the rail is placed a bitumen or polymer shock-absorbing pad. Then the rail is secured to the footing with the aid of a boss and bolt.

A — A



Plan

Reinforcement

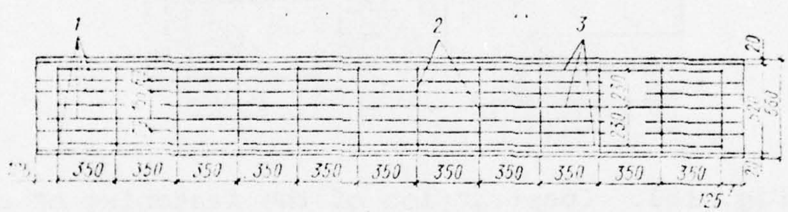


Fig. 152. Construction of reinforced-concrete footing:

1--pre-stressed reinforcement; 2--transverse reinforcement--upper and lower; 3--longitudinal reinforcement--upper and lower; 4--plate with hook; 5--anchor parts (pipe and rod)

REINFORCED-CONCRETE FOOTINGS. The Administration of Passenger Transport for the Moscow Executive Committee developed a construction of a road built on pre-fab, pre-stressed reinforced-concrete footings (Fig. 151) with continuous resting of the rail on the flat, single reinforced-concrete units. The construction is recommended for passenger lines with frequent traffic higher than 20 trains per hour. It is employed only on straight sections

of road when the longitudinal slope is no greater than 4%.

In the construction of the road, attention must be given to ensure the rail's continuous resting on the footing. When making the footing (Fig. 152) reinforcement is accomplished by longitudinal, pre-stressed, hot-rolled reinforcement of the periodic profile. Apart from that, the footing is reinforced by two rows of welded grids made from round, 8-millimeter steel.

In the track-bed parts of the footing (Fig. 153), for a width of 190 mm, a slope of 1 ; 20 is built. Between the rail flange and the footing is laid a rubber ribbon with a width of 180 mm, thickness of 8 mm.

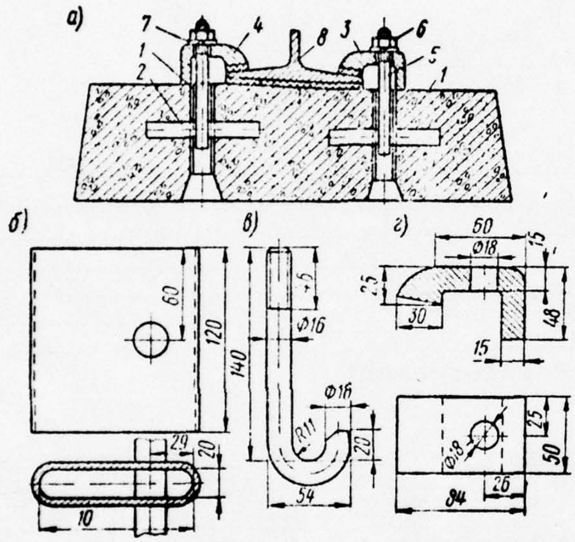


Fig. 153. Construction of the fastening of the rail to the sleeper-footing:

a--general view of the fastening; b--anchor pipe and bar; c--bolt; d--hoisting boss; 1--anchor pipe Ø=120 mm; 2--bar Ø=20mm; l=127 mm; 3--hoisting boss internal; 4--boss, hoisting external; 5--bolt anchor Ø 15 mm, l=170 mm; 6--nut M16; 7--washer spring; 8--elastic padding

Fastening the rail to the footing is given in the form of anchors. The part of the anchor, finished in the concrete of the footing, consists of a pipe with an oval cross section, 120 mm in length. Through this anchor part, in a transverse direction, is inserted a steel bar with a diameter of 20 mm and length of 127 mm. The anchor pipe is made from a length of steel pipe with a diameter of 50 mm. When assembling, a bolt is introduced into the anchor pipe. This bolt catches the transverse bar with its bent end. On the bolt is placed a boss, which rest like a sponge through the rubber padding on the upper edge of the rail's flange, and as a shank on the concrete of the footing. By means of the boss, a thrust washer and a nut, the rail is pressed to the footing.

Footings are laid on a flattened sand layer, one after the other, 3 each for a rail unit.(for a 1 km section of single-track road--480 footings). In a transverse direction, the footings are connected with steel rods, welded to special plates which are fixed in the concrete (2 rods for each footing).

COMBINED FOUNDATIONS. To ensure joint-working of track-bed and tramway-pavement foundations, it is possible to employ the combined foundation of pre-fab reinforced-concrete developed by candidates of technical sciences K. I. Belikovskii and V. S. Naumenko. The structural solution is founded on the use of the particulars of work of railroads on the whole and, in part, the peculiarities of track-bed foundations in combination with the flattened ballast layer. This was done in order to alleviate several unfavorable sides of work with pre-fab pavements both in the overall plan and also in regard to the improvement of the combined working of the road pavement and railway construction.

As is known from the experience of road construction, the basic insufficiencies of pre-fab reinforced-concrete pavements are the difficulties in achieving a uniform compact-resting for the slabs on the spread layer and in constructing suitable stable joints between slabs. At the same time, in track-bed foundations, of both frame and footing types, with installation on ballast,

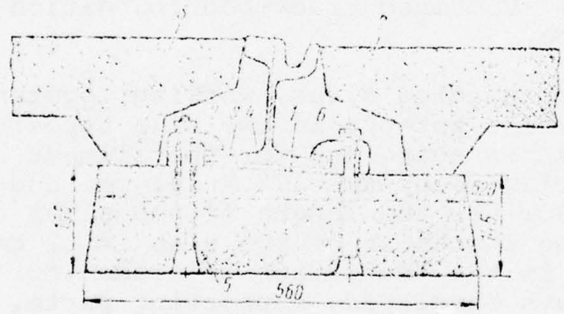


Fig. 154. Slab-footing track-bedding foundation

it is easy to achieve a solid, compact resting for the joint in consequence of reliable connection between track-bed foundation and rail (with the aid of clamping). Taking into account these positive sides of work with track-bed foundations, in constructions of combined foundations, in the first case, foundation and road pavement are joined with hinges, with the aid of the slab restings of the road pavement, restings which are placed directly on the track-bed.

The slab-footing, combined foundation (Fig. 154) is a rigid footing (1) made of pre-stressed reinforced-concrete (under every rail) with reinforced concrete slabs, laid on the shelves of the footings--one on the track side (2) and one on the side between the tracks (3). The rails (4) are attached to the footings (1)

by separate clamping of the anchor-collar type, in the collar (5) of which is set the bolt (6). A thrusting boss (7), which secures the rail to the footing, is fitted on the bolt. In order to obtain a flexible resting under the flange of the rail, a solid padding (8), made from a polymer material, which serves to reduce the magnitude of the wandering current, is laid. The rigid footing is reinforced with bars of a periodic profile, a diameter of 12 mm, and two grids made of ordinary reinforcement; the footing concrete has a mark of 300. Pre-stressing of the reinforcement of the footing is accomplished by electro-thermal means.

The weight of one footing, 4100 mm in length, is 0.8 tons, volume of the concrete is 0.33 m^3, specific outlay of reinforcement steel is 134.5 kg/m^3. The design of the footing allows it to be produced under factory conditions by pouring.

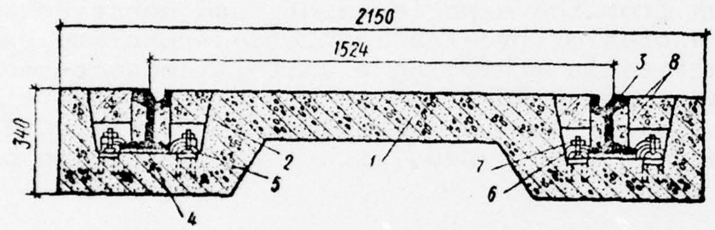


Fig. 155. Combined track-bed foundation of the block type.

Track and track-spacing slabs, working together with the foundation of the slab, are put out in two size types: for installment in the road and track-spacing and for installment on the shoulders. Road and track-spacing slabs are 177 X 141 cm, and shoulder slabs are 177 X 70 cm. However the length of the slabs can be even larger. The working thickness of the slab is 12 cm. For resting on the units, laid in the foundation of roads (for example, footings), slabs have developed, supporting parts, in thickness up to 19 cm. Constructions are reinforced with two welded grids and bars, which pass through the supporting parts. Side surfaces of slabs have a complex profile, which guarantees a space for the placement of interval-spaced, rail clamps and the rail's flange. The volume of the concrete for one road slab is 0.3 m^3, and for the shoulder slab--0.15 m^3, the specific outlay of the reinforcement is 204 kg/m^3 for both types of slab.

The second construction-type of combined foundation is rigid blocks. The middle portion of the block (1) is the road pavement, and the ribs serve as a foundation for the tramway (Fig. 155). The rails (3) are laid in longitudinal, trapezoidal troughs and are attached with the help of separate clamping in the form of pi (5) and thrusting bosses (6) with bolts and nuts (7). Under the flange of the rail is located a solid padding made from a polymer material (4). Between side surfaces of the rail and the trough of the block, are located longitudinal reinforced-concrete beams (2), recesses of the rails are filled with embedded metals (8).

In place of longitudinal beams it is possible to use lean concrete, crushed stone or asphalt. Usually the size of the block is 2040 X 2150, the size of the beams 140 (120) X 4100 mm. However the length can be increased up to the length of the rails

A more perfected construction of the combined foundation, block type, is a rectangle the size of 205 X 204 cm (Fig. 156). Blocks combine units of the foundation of the road and road pavement. Parts of the block, forming foundations, have a slope 1 : 20 on the interior of the rail track. The thickness of the block in these portions is 15--17 cm (the difference is accounted for by the slope). The part of the block, which forms the road pavement, has the minimal thickness of 15 cm, and in zones where it is closer to the rail filament the thickness increases to 34.3 cm. The reinforcement frame of the block consists of two welded grids, bent to correspond to the shape of the block and joined, vertical bars. The concrete volume for one block is 0.8 m^3, specific outlay of reinforcement is 110 kg/m^3.

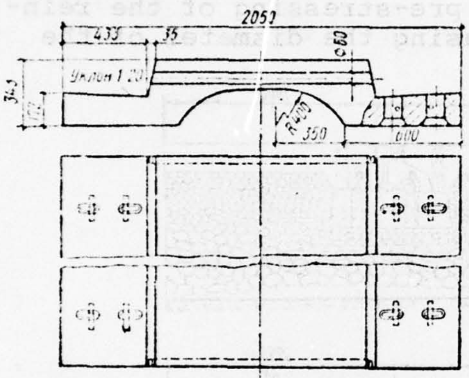


Fig. 156. Perfected construction of the combined track-bed foundations.

Blocks are laid on a layer of sand, prepared and leveled by a templet, and with a thickness of 10-15 cm; the rails are placed and secured in the troughs of the blocks, after which the packing of the ballast from the outer sides of the block toward the track-bed part can be made; packing is accomplished with electro-sleeper-packers or an especially equipped sleeper-packing machines. Then, in the empty spaces between the rails and side surfaces of the troughs are placed longitudinal, reinforced-concrete beams, and the tramway is ready for rolling stock and railless transport.

On double track sections of tramways, the space between the roads (track spacing) can be filled with reinforced-concrete slabs, resting on ballast, shelves of blocks with slab-footing foundation, or other types of pavement (loose, concrete, asphalt).

In Figure 157 are shown constructions of road on combined track-bed foundations of the slab-footing and block types. In both cases, space between tracks is filled with pre-fab, reinforced-concrete slabs.

REINFORCED-CONRETE TIES. In the practice of planning and building roads for trams in cities, reinforced-concrete ties of various constructions are widely used.

The most expedient wire-reinforced pre-stressed concrete ties are made with wire of a periodic profile; such wire ensures self-anchoring in the concrete. Sufficient cohesion between the reinforcement and the concrete is accomplished through the use of smooth wire, wound in pairs.

Between the diameter and the limit of strength, and also the specific surface of the cold-flattened wire, there is an inverse relation; that is, the smaller the diameter of the wire, the greater its strength and the larger the surface of coupling with the concrete. Therefore, it is more advantageous to employ a thinner wire, because the weight of the reinforcement diminishes and the possibility of increasing the pre-stressing of the reinforcement is created. However, decreasing the diameter of the

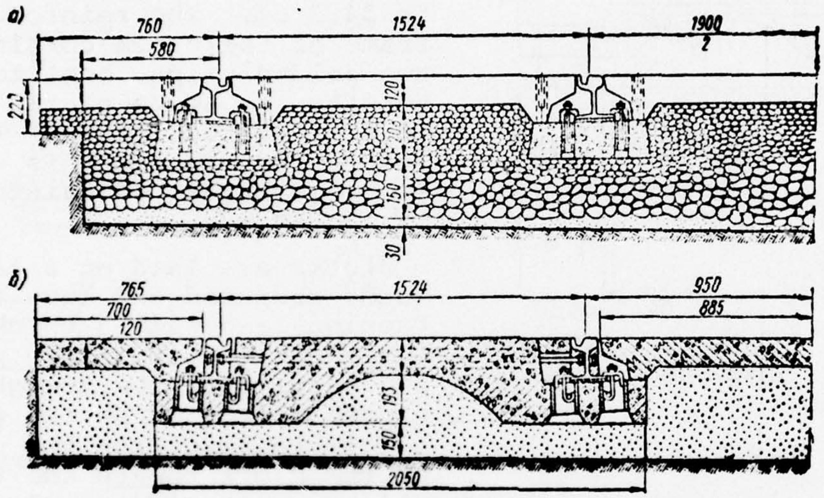


Fig. 157. **Road constructions on combined foundations: a--slab-footing type; b--block type**

cord leads to the increasing of its quantity and complications in the technology of its production. The optimal diameter of wire is 2.5-5 mm within a limit of strength of 150-200 kg/mm^2.

In several tramway administrations, reinforced-concrete ties of the railway type are used: squared sleepers, reinforced by pre-stressed, high-strength wire. Such ties have variable width, which increases near the ends; this increases the supporting area in places of the largest stress on the ballast and, besides, raises the stability of the road in the transverse direction. To increase the absorption of shock, on the lower surface of the tie is created a raised surface, which consists of a square recess with an area 70 X 70 mm and a height of about 10 mm. The tie is reinforced with 44 cords with a diameter of 3 mm, smooth, and wound in pairs. The

strength limit of the reinforcement is 1900 kg/cm^2, pre-stressing is 11,700 kg/cm^2. Reinforcement in the tie is 6.9 kg, concrete of grade 500, weight is 250 kg.

In track-bed portions, the surface is made with a slope 1 : 20, which allows for the use of flat liner or coupling without liners. Bolting with rails is separate, of the type "K" in two

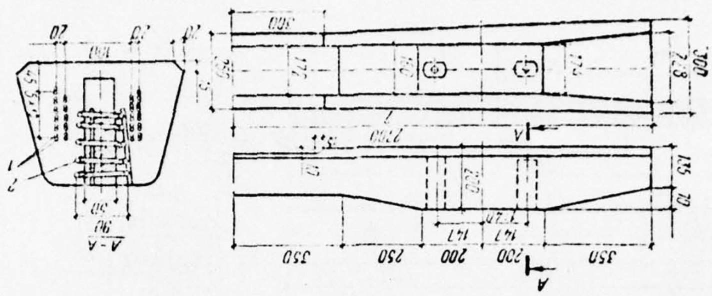


Fig. 158. Reinforced concrete tie of type C-56: 1--working reinforcement; 2--spiral

wood screws. Bolting of liners to the rails is R-50 and by paddings of pressed timber (Fig. 159). Bolting consists of a double-ribbed liner, embedded bolts, rigid thrusting bosses, washers and nuts for embedded bolts. Liners are fastened to the tie with wood screws, and rails are fastened with the aid of thrusting bosses, embedded bolts with washers.

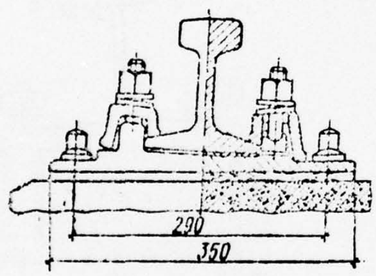


Fig. 159. Separate bolting of a rail to a tie, type "K"

In 1955, for use in Moscow, a standard construction of the squared-sleeper type was developed; it has a trapezoidal cross section with a height of 160 mm, length of 2700 mm. Reinforcement is done with 24 wires with a diameter of 2.5 mm with ultimate resistance of 20,000 kg/cm^2. Pre-stressing of the reinforcement is 12,000 kg/cm^2, concrete of grade 500, weight of the tie 258 kg. Subsequently, in Moscow, a second variant was developed--lightweight-sleeper (Fig. 160). The height of the tie was reduced by 120 mm to 2500 mm. The tie was left in its squared-sleeper form with a trapezoidal cross section, with a width of the lower bed--250 mm, upper bed--230 mm. All ties weigh 173 kg. The tie is reinforced with 28 wires with a diameter of 2.5 mm. Bolting of the rail to the ties is shown in Figure 161. The liner (1) is installed on the tie (2) by means of an elastic padding (3). The bolt (4) is led through an oval pipe (5) in the body of the tie and has a thrusting boss (6), spring washer (7) and nut (8). The rail (9), installed on a

liner, is attached with a thrusting boss (6) through a padding (10).

As a variant of the pre-stressed tie is the double-hinged tie, reinforced by two bundles of wire, put into a channel (Fig. 162). The tie consists of two extreme (1) and one mean block (2) between which are placed spacers (3), which make up the hinges. Such a solution reduces the bending moment in the middle portion

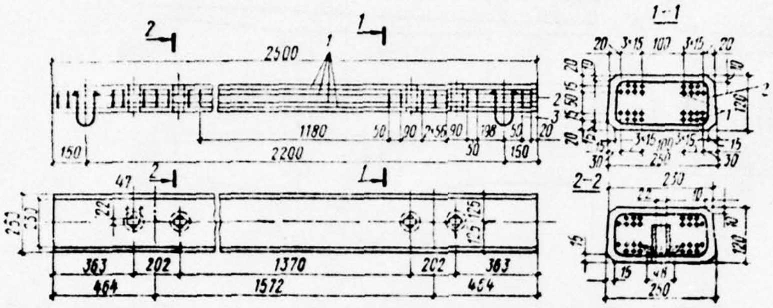


Fig. 160. Wire-reinforced tie for tramways:
1--longitudinal reinforcement; 2--clamp;
3--hoisting loop

of the construction and reduces the cross section of the tie. Channels with working reinforcement (4) are injected with a cement grout (after the stressing of the wire). For bolting the rails to the tie, wooden inserts are provided.

The K. D. Pamfilov Institute of Scientific Investigation in Leningrad developed a construction for wire-reinforced squared-sleeper ties.

In all constructions, it is recommended to employ concrete of grade 500. In Table 47 is given the list of technical characteristics for the most widely used reinforced-concrete ties.

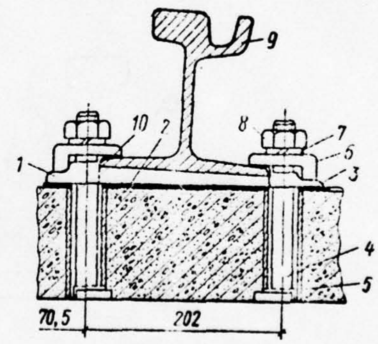


Fig. 161. Bolting of rails

PRE-FAB PAVEMENTS FOR TRAMWAYS. Road coverings for tramways have the same qualities as do pavements for the traversed portions of streets; however, the two work differently. The upper structure of tramway withstands elastic strain, which arises under the traffic of trains; at the same time, the constant bending of rails and foundation is harmful for the road pavement, lowering its resistance. For the most part, strains arise along the rails, because road pavement, which does not undergo simultaneous stress

with the rails and foundation, and is not joined to them, cannot follow their elastic deformations.

Normally in roads for tramways, the same type of road pavement that is on the adjacent traversed part of the street, is used (asphalt-concrete, stone blocks or cobblestone pavement).

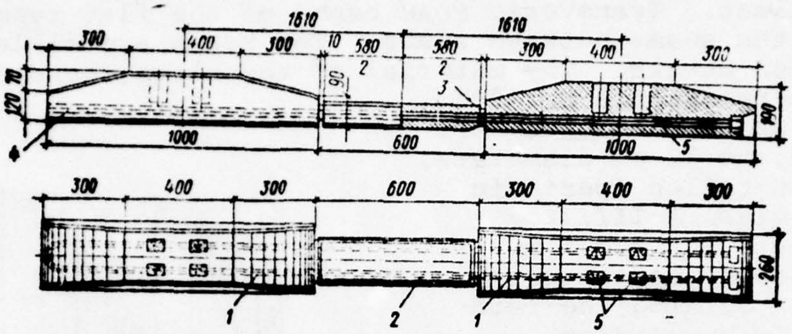


Fig. 162. Double-hinged, double-bundle reinforced-concrete slab

TABLE 47

Sleeper type	Dimensions of sleeper, cm Length	Width	Height	Weight of sleeper, kg	Outlay of Reinforcement, kg
Railway	270	30/25	20.5/13.5	250	6.9
Moscow type (ordinary)	270	25	16	258	6.8
Moscow type (alleviated)	250	25/23	12	173	6.1
Leningrad type	270	28	20/14	245	6.8

They have structural discrepancies due to the separate working of the rail and road pavement. These discrepancies can be eliminated with the use of a track-bed of the combined type or a pavement made of pre-fab reinforced-concrete slabs.

In 1963, in Moscow, standard constructions of flat and ribbed slabs for pavements of detached and non-detached tramway beds were developed.

Slabs of pavement for the non-detached bedding are calculated for a stress of H-30, and for the detached bedding--the stress from the vehicles which the tramway serves.

At the present time, slabs of a length 3.2 m are laid; however, this does not exclude the possibility of laying slabs of a smaller size. Slabs with the dimensions 0.9 X 0.7; 1.4 X 0.9; and 1.8 X 0.9 m can in different combinations be laid on roads, the

track-spacings and shoulders. For curved portions, slabs 0.9 X 0.7 m are stipulated. In Fig. 163 are shown the pavements for tramway beddings made out of pre-fab slabs.

In all instances, rails of the type TV-60, are employed; they are laid on reinforced-concrete sleepers, which allow the overall dimensions of reinforced-concrete slabs. The slabs are placed on a sand ballast. Transverse road beams of the flat type are placed in the seams between slabs. The seams are filled with a hot, bitumen mastic. The material of the slabs--concrete of grade 400, frost-resistance Mrz-200. The slabs use a reinforcement, with 8, 10,and 12 mm diameters, made of hot-rolled (periodic profile), class A-III; for diameters of 3, 4 and 5 mm, cold-flattened, smooth wire, class B-1. Joining the reinforcement is by welding. Seams between slabs are filled with sand.

At the factory, slabs should be carefully marked as to what kind of bedding (detached or non-detached) they are intended.

In Figure 164 is given the design for the laying of slabs with a length of 3200 mm on a detached bedding. Laying of slabs on shoulders and track-spacing can be changed when using slabs of a different size.

Reinforcement of the pavement slabs is accomplished with spacial frames, assembled from flat units (Fig. 165). A three-dimensional frame is formed by welding the flat frames (longitudinal) of K-1 type and flat frames (transverse) of K-2 type. The overall outlay of metal for one slab is 60.7 kg.

For the upper pavement

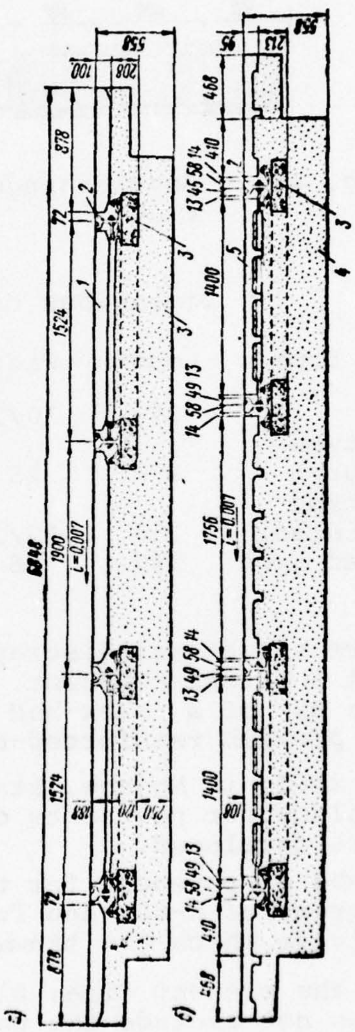


Fig. 163. Tramway pavement: a--flat slabs; b--ribbed slabs; 1--flat slab of pavement; 2--frame tie; 3--rail; 4--ballast layer; 5--ribbed slab

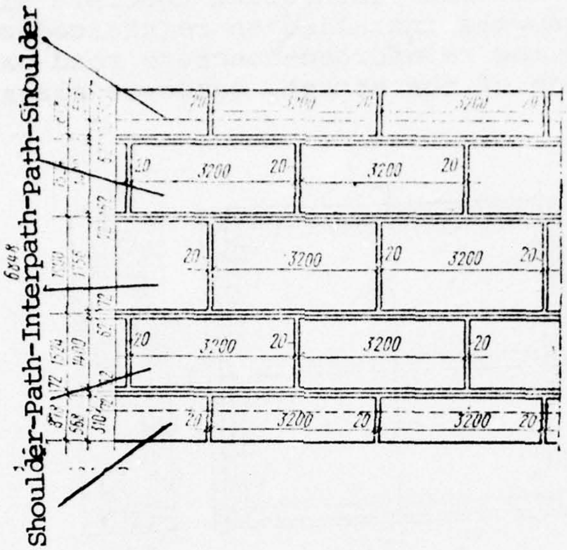


Fig. 164. Laying of pre-fab slabs on detached tramway bedding

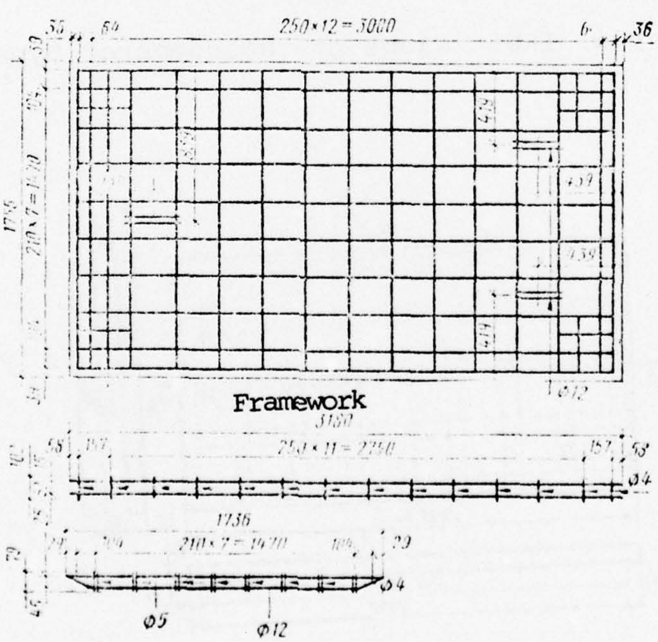


Fig. 165. Reinforcement of a slab, intended for laying in track-spacing

in tramways when using stable, track-bed foundations or block constructions, pre-stressed, reinforced-concrete slabs are recommended. In tramways installed on reinforced-concrete foundations, when using reinforced-concrete road pavement in the traversed portion of the street, cambered slabs resting

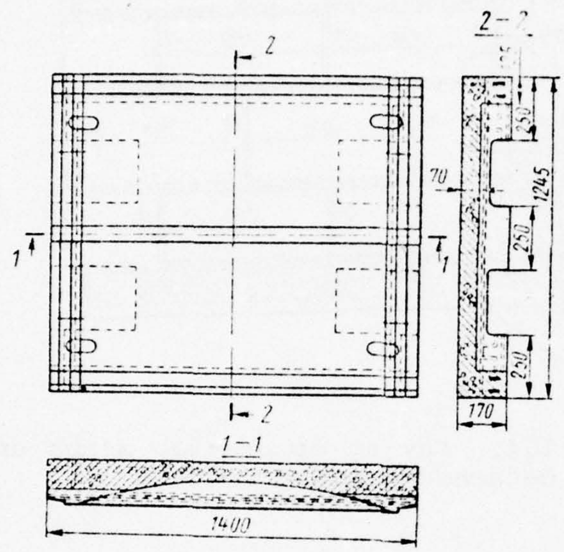


Fig. 166. Slabs of the cambered type.

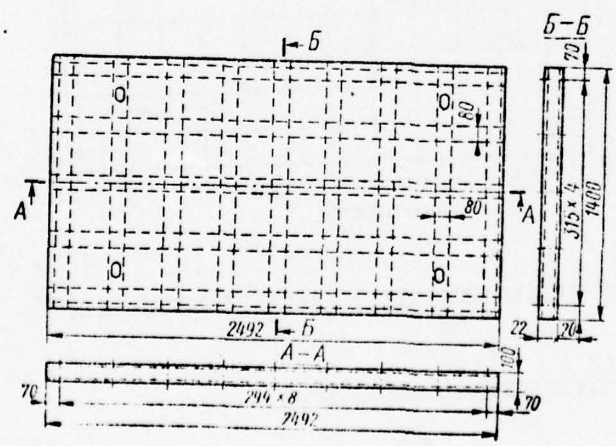


Fig. 167. Flat slab

on the flange of the rails, and flat slabs (laid on sand layer or crushed stone) are recommended. Cambered slabs (Fig. 166) are made in two sizes: 1400 X 1244 mm (road slabs) and 1780 X 1244 mm (track-spacing slabs). In the cross section of these slabs are designed three ribs: two at the edges and one in the middle. The thickness of the arch in the middle of the slab is 700 mm, at the edge--175 mm. The slab is reinforced in the ribs, each with two vertical rows of reinforcement. In the lower, expanded zone there are six wires in a vertical row. In the upper zone--two wires each. In the direction of the axis of the road, the slab is reinforced with six rods with a diameter of 10 mm. The grade of concrete is 400. The weight of the road slab is 435.5 kg, weight of the track-spacing slab--562.5 kg.

The flat slabs (Fig. 167) for the track-spacing are made with dimensions 1780 x 2492 mm, and for the pavement of a railroad--1400 X 2492 mm, their thickness is 100 mm. Slabs are reinforced in two directions with high-strength wire of a diameter 4 mm, grade of concrete--400.

The construction of pre-stressed, reinforced-concrete slabs for road pavement on tramways is developed by the Administration of Passenger Transport of the Moscow City Executive Committee together with the Institute for the Study of Reinforced-concrete.

31. PRE-FAB SIDEWALKS AND CURBSTONES

Sidewalk pavements should be even and rough-finished in order to ensure safe footing for pedestrians. The strength of sidewalk pavements should be enough to support occasional service, motor-transport.

When calculating the thickness of the pavement of sidewalks and pedestrian paths, the stress for one wheel of a car is taken: For single cars of limited weight (up to the GAZ-51 model car)--1200kg; for various other vehicles--2750 kg (5.5 tons for an axle), the absolute value of elastic deformation should be no less than 275-300 kg/cm^2.

Along with asphalt-concrete and monolith cement-concrete pavements on sidewalks of city streets, pieced pavements are also used. Such pavements are made with tiles (inlays), clinker bricks, cement-concrete, asphalt-concrete and ceramic slabs. With small tile pieces (inlays), pavements of the most varied designs are laid.

From concrete, slabs are made in several sizes: small (with sides up to 40 cm), middle (up to 75 cm), and large (more than 75 cm). The smaller slabs are not reinforced as a rule, middle and large slabs are reinforced with pre-stressed reinforcement.

Concrete slabs are laid with a seal bond and without a bond (with a mixture of sand, asphalt or cement for filling). Sometimes for filling the seams, a bitumen mastic is used.

In individual cases (on pedestrian paths, in parks and squares) seams between slabs are arranged with a larger space in which earth with seeds for decorative grass is put. In the

majority of cases slabs are laid on a sand foundation with a thickness of 10-15 cm. Under considerable stresses, the sand can be stabilized with cement or asphalt.

The most common slabs, made of concrete, are square with a side of 35-50 cm, and a thickness of 4-7 cm. Also for paving sidewalks, concrete slabs of hexagonal shape are used with success. They have a side of 15 or 30 cm and a thickness of 5 or 6 cm.

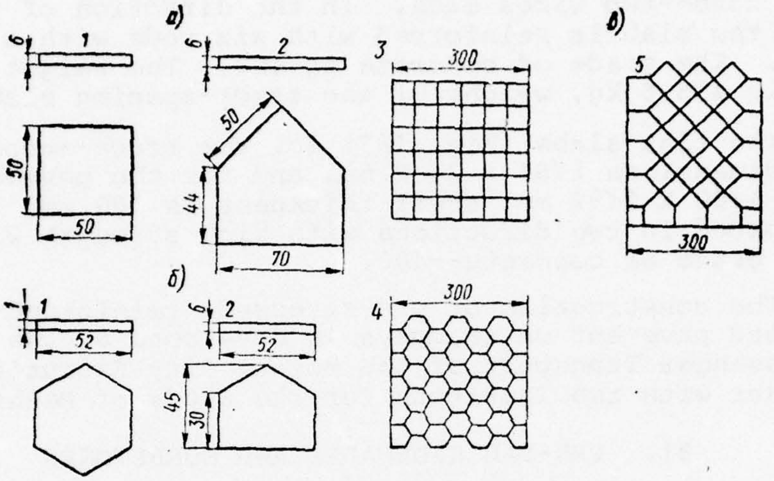


Fig. 168. Square and hexagonal sidewalk slabs:

a--square slab; b--hexagonal slab; c--design of slab installation; 1--basic slab; 2--edged slab; 3--installation of slabs in rows; 4--installment of hexagonal slabs; 5--installment of square slabs on a diagonal

Sidewalk slabs can be made in factories with the employment of the method of forced, vibration-rolled concrete. For this process, the slabs should have a grade of concrete no lower than 400, and a frost-resistance no less than 100 cycles. The size of the slabs can be up to 75 X 75 cm with a thickness of 6 cm.

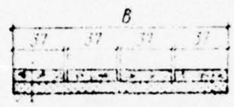
Temporary, technical indicators of the Ministry of Communal Administration recommend the building of sidewalks with pre-fab pavements made of concrete and reinforced-concrete slabs with the dimensions and configurations given in Fig. 168.

Pre-fab pavements for sidewalks and park paths, made of cement-concrete slabs, are used in the cities of the Baltic Sea areas, in southern cities of the Russian Federation, the Ukraine and in Siberia.

The Ministry of Communal Administration of the Ukrainian Republic recommends the following types and sizes of sidewalk slabs:

a) type I (Fig. 169)--rectangular concrete sidewalk slabs with the dimensions 37 X 37 X 6 cm, used for the building of sidewalks with a width in multiples of 0.75 m. The given type of sidewalk slabs has two types: 1--basic unit of sidewalk pavement, weight 20 kg; 2--additional unit used only in end, planed portions, weight 10 kg.

b) type II (Fig. 170)--hexagonal, concrete sidewalk slabs with a side of 29 cm, used for building of sidewalks with a width



Rectangular concrete slab
dimensions 37 x 37 x 6 cm
Spreading layer, thickness
5 ÷ 10 cm

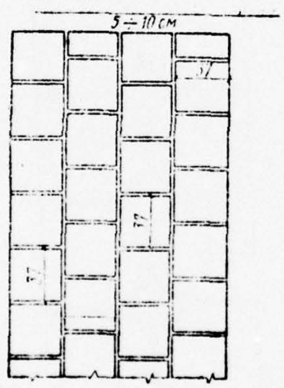
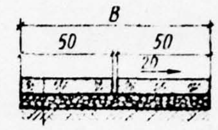


Fig. 169. Pre-fab concrete pavements for sidewalks (type I)



Hexagonal concrete slab,
thickness 7 cm
spreading layer
thickness 5 ÷ 10 cm

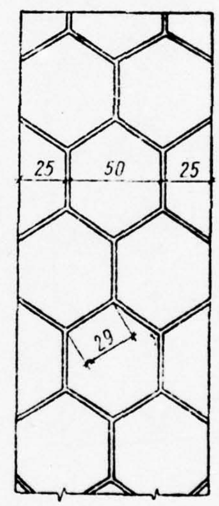
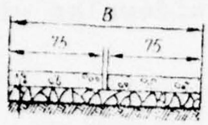


Fig. 170. Pre-fab concrete pavements for sidewalks (type II)

in multiples of 1.0 m. The given type of slab has two size-types: 1--basic unit of sidewalk pavement, a concrete hexagonal slab with a weight of 38 kg; 2--additional unit used for portions of the sidewalk which touch the border, building lines, etc., weight 19 kg.

c) type III (Fig. 171)--octagonal, concrete sidewalk slabs with a side of 30 cm, used for sidewalks with a width in multiples of 0.75 m.

The given type of sidewalk slabs has three size-types: 1--basic unit of sidewalk pavement, an octagonal concrete slab with a weight 76 kg; 2--additional units used in places for



Octagonal concrete slab h = 7 cm
Spreading layer h = 5 ÷ 10 cm

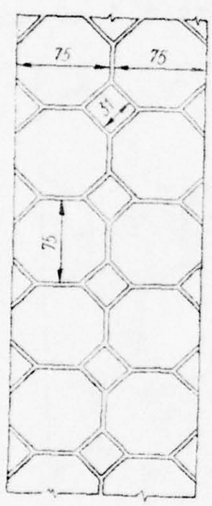
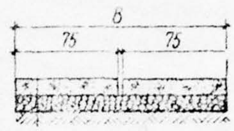


Fig. 171. Pre-fab, concrete sidewalk pavement (type III)



Concrete Sidewalk slab h = 7 cm
Spreading layer of sone sieving h = 5 ÷ 10 cm

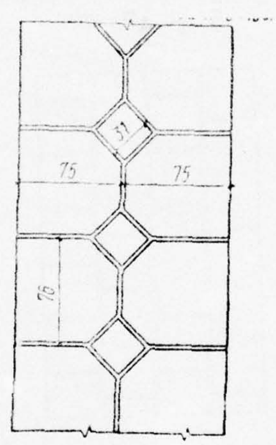


Fig. 172. Pre-fab, concrete sidewalk pavement (type IV)

joining four slabs of type 1, weight 17 kg; 3--additional unit used on sides which touch borders, lawns and building lines, etc., weight 10 kg;

d) type IV (Fig. 172)--rectangular, concrete sidewalk slabs with two corners cut off, used for sidewalks with a width in multiples of 1.5 m. The given type has two size-types: 1--basic unit of sidewalk pavement, weight 90 kg; 2--additional unit used to join the cut-off corners of slabs, weight 17 kg.

In view of the materials used for building the spread layer under sidewalk pavements, the following can be recommended: stone-sieving, sand, prepared bitumen, etc.

The principal requirement for the spread layer: sufficiently high resistance to natural factors that will ensure the sidewalk pavement strength, and evenness in the course of a long period.

The Moscow Engineering Design Institute recommends, for sidewalk pavements, flat, concrete hexagonal (Fig. 173) or rectangular slabs (Fig. 174) and ribbed, vibration-rolled, rein-

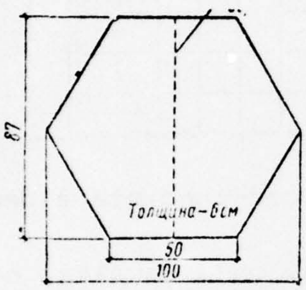


Fig. 173. Flat, hexagonal sidewalk pavement, concrete slab

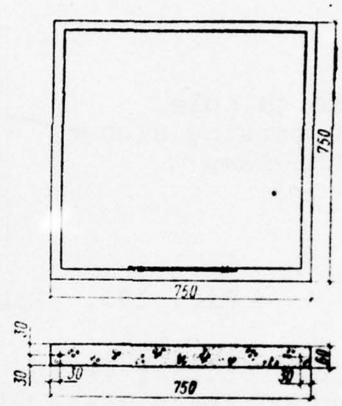


Fig. 174. Flat, rectangular sidewalk pavement, concrete slab

forced-concrete slabs (Fig. 175). The basic technical and economic indicators for these slabs are given in Table 48.

The standard stress for these slabs is as follows:

a) pressure from one wheel is 4.74 tons, when slab is installed on wide sidewalks, squares and access walks in building complexes with little traffic from transport and irrigation machinery.

b) pressure from one wheel is 2.75 tons (in accordance with SNP II-K. 3--62, 3.25) when slab is installed on sidewalks which can be traversed by automobiles and service machinery;

c) Pressure from one wheel is 1.29 tons (which corresponds to the stress of the half-load of transport trucks GAZ-51-A), when slabs are installed on sidewalks which can be traversed by trucks for repairs of overhead wire.

Making of flat slabs is stipulated: by the forced, vibration-rolled method or another method which guarantees the quality of the slabs; making of ribbed slabs--vibration-rolled method of

construction developed by the engineer I. Ya Kozlov. In any case, the following conditions must be observed: A grade of concrete no less than 300, frost-resistance 100-200 cycles. No matter which means of slab construction used, strength and frost-resistance must be guaranteed.

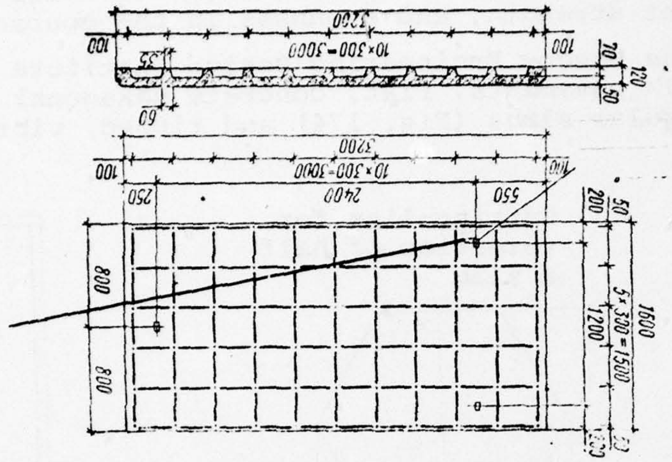


Fig. 175. Ribbed, reinforced-concrete sidewalk slab

Of interest is the installation, on sidewalks, of flat, reinforced-concrete slabs with the dimensions 2.25 X 1.5 X 0.1 m. Such slabs allow for the arrangement of sidewalks with minimal numbers of seams, projected for three or six lanes of movement (Fig. 176).

In 1970, at the K. D. Pamfilov Academy of Communal Administration (candidate of technical sciences Timofeev, A.A.), together with the Institute of Moscow Builders of the Moscow City Executive Committee, was worked out in GOST 17608-72, "Concrete Pavement Slabs". In this study, the authors stipulated the methods of manufacturing sidewalk slabs made from sand and silicate concretes; square, rectangular and hexagonal shapes were discussed. Aside from this, for edged slabs, slabs of quadralateral, triangular, and pentagonal shapes can be used.

Fig. 176. Sidewalk made of flat, reinforced-concrete slabs

TABLE 48

Square slabs can be made in five different types: with dimensions of 200 mm, 250 mm, with a thickness of 40 (60) mm; 375, 500 mm, with a thickness of 50 (70); and 750 mm with a thickness of 60 (80) mm. The larger thickness is used on portions of sidewalks where heavy transport trucks can move.

Rectangular slabs are of five types: 375 X 250 mm, 500 X 250 mm with a thickness of 40 (60) mm; 500 X 375 mm with a thickness of 50 (70) mm; 750 X 375 mm with a thickness of 60 (70) mm and 750 X 500 with a thickness of 60 (80) mm.

Hexagonal slabs are divided into three types: with a side of 250 mm with a thickness of 40 (60) mm; 375 mm with thickness 50 (70) mm and 500 mm with a thickness of 60 (80) mm. Allowed divergences from these dimensions should not exceed the following magnitudes: in length and width of slab with dimensions between 500 and 750 mm, ± 3 mm, between 200 and 375 mm, ± 2 mm; in slab thickness, ± 2 mm.

In city conditions, the conjunction of the traversed part of streets with sidewalks, lawns, raised mediums and islands, is accomplished with curb stones made of concrete or granite.

For city road construction, the manufacturing of straight, corner and curved curb stones is stipulated for the bordering of traversed parts of roads, sidewalks and lawns.

The following gauges of curb stones are manufactured: straight series

TABLE 48

TECHNICAL-ECONOMIC INDECES FOR SIDEWALK SLABS

Slab-group	grade	Short description of slabs	Dimensions, cm			Outlay per m^2			Value/m^2, pavement, rubles			
			a	b	h	weight m	concrete, m^3	metal kg	Tempering value 1 m^2, free at factory	sand foundation, equal to 10 cm	pavement	in all
1	TSSh-2	Solid, hexagonal . . .	50	87	6	0.097	0,06	--	1 - 91	0.44	0.35	0.79
	TSSH-1	Same as above	35.5	52	4	0.026	0.04	--	1 - 27	0.44	1.67	2.11
2	TSP-2	Solid, rectangular	75	75	6	0.085	0.06	0.55	1 - 91	0.44	2.35	2.79
	TSP-1	Same as above	37.5	37.5	4	0.014	0.04	--	1 - 27	0.44	1.63	2.07
3	TVP-2B	Ribbed, vibration rolled . .	320	160	12	1.0	0.078	4.02	3 - 16	0.44	3.76	4.20
	TVP-5A	Same as above	320	160	16	1.33	0.104	6.4	4 - 45	0.44	5.22	5 - 66

TABLE 49

Grade	Height, mm	Width, mm at top	Width, mm at bottom	length	radius of curvature	Purpose
P1	300	120	150	1000	-	For separation of access roads from sidewalks and lawns
P2	300	150	180	1000	-	Same as above, for arterial streets
P3	450	150	180	1000	-	Same as above, for access ramps and tunnel
P4	600	170	200	1000	-	Same as above, on bridges
P5	200	65	80	1000	-	For separation of sidewalks from lawns
V-P1	300	80	150	1000		For joining approach ramps with roadway and sidewalks, using curb stones of grade P1 and the plane of the sidewalk on one level
V-P2	300	80	180	1000	-	Same as above, using curb stones of grade P2
K-R3-P1	300	120	150	-	3	For separation of roadway from sidewalks and lawns on curves, in conjunction with curb stones P1
KR5-P1	300	120	150	-	5	
KR8-P1	300	120	150	-	8	
KR12-P1	300	120	150	-	12	
KR3-P2	300	150	180	-	3	
KR 5-52	300	150	180	-	5	Same as above, for arterial streets, in conjunction with curb stones P2
KR 8-52	300	150	180	-	8	
KR12-P2	300	150	180	-	12	
KR 3-V-P2	300	80	180	-	3	For separating the roadway from shoulders and dividing lanes with the possibility of access over the rounded-off curbs using stones P1
KR 5-V-P2	300	80	180	-	5	
KR 8-V-P2	300	80	180	-	8	
KR12-V-P2	300	80	180	-	12	
U-P1	300	120	150	630	0.4	For formation of corners using curb stones P1
U-P2	300	150	180	630	0.4	For formation of corners using curb stones P2
U-P5	200	65	80	400	0.25	For formation of corners when using stones P5

(P1, P2, P3, P4, P5), straight approach (V-P1, V-P2), corner (U-P1, U-P2, U-P5) and curved (Fig. 177).

In Table 49 are given the specifications for curb stones according to GOST 6665-63.

Concrete curb stones are manufactured from concrete no lower than grade 400 in strength. In agreement with GOST, concrete curb stones are manufactured for frost-resistance according to the following requirements: Mrz 100--for regions with mean monthly air temperature for the coldest month from 0 to minus 10° C; Mrz 150--10 to minus 20° C; Mrz 200--below minus 20° C.

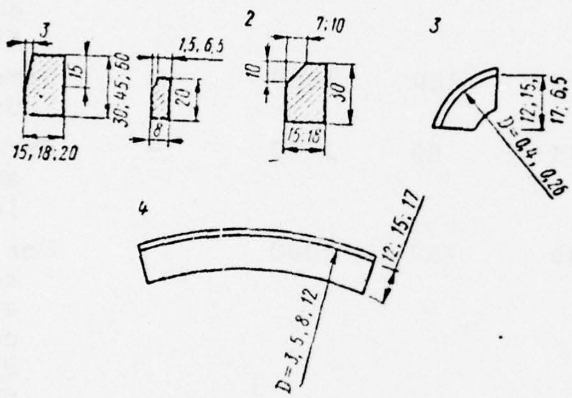


Fig. 177. Gauges for curb stones

1--straight; 2--straight approach;
3--corner; 4--curved

The existing standard constructions limit the length of curb stones to 1 m. Experience has shown that with such dimensions, the procedure of laying curb stones is complex and lends itself poorly to mechanization.

One of the means of raising the degree of industrialization of construction is the lengthening of curb stones with installation by automotive hoist.

The construction of a curb stone, made by the forced vibration-rolled method (Fig. 178) has been developed by the All-Union Correspondence Construction-Engineering Institute and the KTB of Rolled-concrete. To eliminate the work of building a monolith foundation under the border, a curb with T-shaped cross section has been developed. Reinforcement of the curb stone with a length of 6 m is accomplished with three pre-stressed wires.

Another direction in the improvement of the technology of border installation is the suggestion of the roads laboratory of the NII of Moscow's building industry: secure the curb stone directly to the concrete pavement with glue compounds on a

polymer base (Fig. 179). This method allows for the reduction of the height of the curb stone (and, consequently, its weight), simplifies the mechanization of the installation of curbs, and makes it possible to reduce the outlay of concrete.

For the glueing compounds, used in such work, there are specified technological and strength requirements: the thickness of the seam is 1.5--3 mm; in order to avoid shrinkage, quick-evaporating substances in these glues should comprise no more than 10% of the compound. Acid-hardening glues, which corrode the concrete, are absolutely not acceptable. Only cold-setting

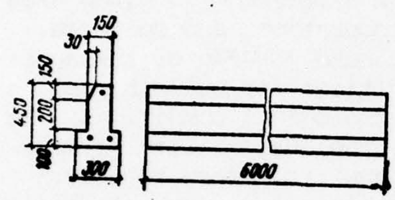


Fig. 178. Curb stone of great length

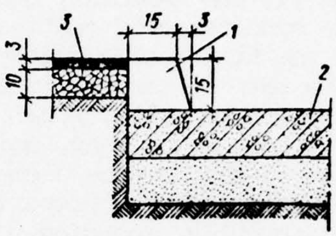


Fig. 179. Design for the installation of a curb stone by glueing:
1--curb stone; 2--cement-concrete pavement; 3--sidewalk

adhesives are permitted. The material of the adhesive seam should be water- and frost-resistant, both of which are necessary so that the strength of the material of the seam to the concrete should be no less than 100% of the strength of the concrete when tensed. Such requirements can be met only by compounds which are obtained on a base of catalytic-setting, thermoreactive resins with a strength under contraction of 600-900 kg/cm^2.

The required qualities, for example, are met by epoxide compound used for the glueing of curbs in a part of Moscow in 1964. After many years, the curb remains in good condition.

CHAPTER VII

PREFABRICATED SURFACES FOR TEMPORARY ROADS

32. GENERAL INFORMATION

The term of service for temporary roads is defined by the conclusion of the projected transportation: the end of a construction job, an operations on a unit being serviced in whole or in part, for example, a large-scale foundation area (if the temporary roads were built for removal of soil from a pit), the conclusion of cutting down a forest of a given area (for logging roads), the finish of a quarrying operation, and so forth.

Depending on the term of service, the intended volume of transportation, the types of motor vehicles, local conditions for building and maintaining the road (the time of year, soil-hydrological conditions, the single or multiple use of the surgace elements, the availability of construction supplies or materials for preparing them) temporary road surfaces are arranged differently according to durability and work capability, while raw materials used for them include: wood, metal, fiber, resin, veneer, light and heavy concretes, reinforced concrete, prestressed reinforced concrete, sand concrete, silicate concrete, and others.

As a rule, surfaces for temporary roads are enmarked for multiple use on different sections of one and the same road or on various roads. Apart from that, temporary roads of long wearing materials (when this is economically justified) can remain as the basis for permanent. roads.

Prefabricated surfaces for temporary roads are subdivided according to building method into track-type (fig. 180) and continuous. In track surfaces the roadway part of each traffic strip consists of two wheel tracks and a median gap. The width of each wheel track varies from 1.0 meter to 1.25 m. and the width of the median gap is set at 0.9 m. although sometimes it can be reduced to 0.7 m. Besides substantial savings on materials, it is appropriate to include the convenience of transporting the structural elements amont the advantages of the track-type surface, since the width of the wheel track, and consequently the slabs from which it is assembled, does not exceed 1.25 m., while their length is most often set roughly at 3.0 m.

A continuous roadway can be formed either using slabs of track-type surfacing or with special rectangular slabs having dimensions on a scheme from 1x1 m. up to sizes limited only by the possibilities of installation and transportation.

The construction of temporary roads w::th prefabricated surface elements has received significant widespread application. These roads extend hundreds and even thousands of kilometers, operating simultaneoudly throughout the country, appearing as a sometimes important component of the road network of some branch of the national management (the road network of the lumber industry may serve as an example), or of a given time period. In several branches of the national management special cadres of road workers, road-building and road-maintaining organizations, plants for the preparation of wurface elements, and research establishments are created for the construction and maintenance of temporary roads.

In the majority of cases for temporary roads surfaces are used that are prefabricated and meant for easy disassembly, that is, those destined for multiple use. They are most often used for detours around road or bridge units under construcioon, approach roads to pits, factories and ordinance yards, detours during repairs on automobile roads, for the logging industry's temporary roads, units of civil and industrial construction and agricultural roads.

Fig. 180. General view of a prefab-reusable track surface made of reinforced concrete slab.

For the needs of the lumber industry at the present time there are about 1000 km of road built with surfaces of prefabricated and prefabricated-reusable reinforced concrete slabs.

In the lumber industry 200 to 300 km of reinforced concrete slab roads are put in operation annually, and plants now under construction will allow this construction to reach 1000 km per year in the very near future.

This same branch of industry maintains around 8000 km of roads with wood surfaces, which at the present time in a number of cases are not only prefabricated, but prefabricated-reusable.

Prefabricated surfaces for temporary roads have also found wide acceptance in conditions of urban industrial-civil construction. Thus for example, in the city of Moscow 350 to 400 thousand square meters of such surgaces are built every year.

The growing adoption of prefabricated surfaces for temporary roads is explained by their substantial advantages over other types of surfaces for temporary roads. Such advantages include the following:

1. The possibility of repeated use of the same prefab-reusable surfaces on different sections of a road or on different roads. The multiple use of such surface slabs leads to a substantial reduction in building costs of temporary roads, a reduction in material expenditures and an increase in the operational indeces of the roads.

2. The use of the surface for a limited time and consequently a substantial reduction in the number of vehicle passages across a given surface without its relocation, lead to the possibility of lowering demands for establishing temporary roads.

3. The possibility of mass, factory manufacture of component elements of prefab-reusable surfaces.

4. With the availability of these surfaces not only is the expenxe of fuels, lubricants and resins lowered, and the running times of motor vehicles between repairs increased, but the possibility of irregular delivery of materials is excluded, a frequent problem under roadless conditions. All this leads to a lowering of the cost-price of transportation and to a noticeable improvement in all indeces of the enterprise.

5. Such advantages of prefab surfaces for permanent roads as industrial manufacture, the possibility of quick opening to traffic, the extension of the building season (practically to year-round), and a rise in the rate of expenditures of energy and means thanks to turning surface-building into an assembly-installation process, are preserved in the case of their use in the surfaces of temporary roads.

6. In cases where it is economically wise, some structures of prefab surfaces for temporary roads at the end of their operation can be used without resulting as foundations for permanent roads.

Track-type surfaces, including prefabricated types, have received significant development on temporary automobile roads.

Wooden structures of prefab surfaces for temporary roads were adopted on military roads during World War II in the favor of track surfaces of wooden plank (fig. 181) and square-beam panels. Experience in their operation showed that these are convenient, sufficiently durable and hard working surfaces. They stood up to automobile traffic with speeds of 40 to 60 km/hr. without considerable repairs in those cases when they were laid over cross-beams, directly on the soil of a sub-grade with assured water drainage.

In this same period the basic deficiencies of such surfaces were discovered. Chief of these is the destruction of uniform strength due to weakening of the wheel tracks by seams between the slabs. In these places significant vertical deformations arise which often proved residual, and accumulating, led to the destruction of the surface. This process is further hastened by the fact that moisture falling during rainstorms into the gaps between tracks filled up depressions which had formed beneath the slab joints and diluted the soil In this fashion the efficiency of prefab surfaces compared to monolithic surfaces (uniformly strong along their entire length) gradually gradually diminished. Their circumstance defined the area of application for prefab surfaces - for cases of urgent road building for short terms of operation. In the necessity of their prolonged use they were laid on a firm foundation. For example, temporary surfaces of plank panels for improving operating conditions for vehicles and roads were widely adopted as a top layer surface over timbered cross decking. In the same period we find several applications of metal prefab-reusable constructions of track surfaces for temporary automobile roads.

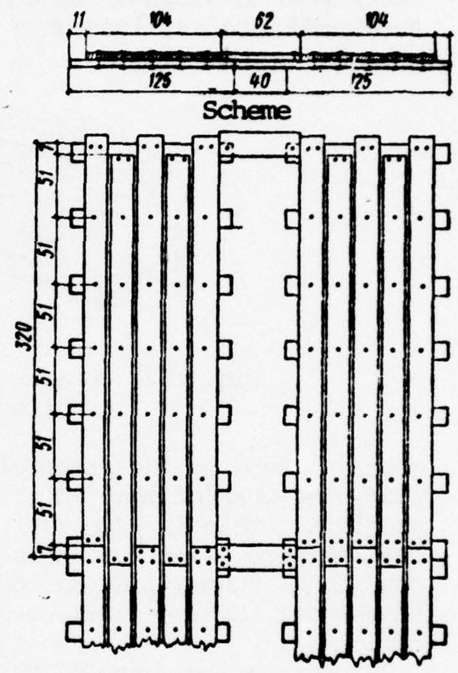


Fig. 181. Prebab track surface of the World War II period made of plank panels.

In 1939 in England a construction method was devised for paving with artinlated revetment wound around a drum (fig. 182). The width of the belt is about 2 in., the two other measures of each element being 0.23 x 0.15 in. These elements are joined together with a flexible reinforcement. The basic advantage of such structures (they are designed in different countries and in the USSR to be made of reinforced concrete, metal and wood) is an increase in the rate and reduction of labor expenses in the laying process, which consits of unwinding the surface off the drum directly onto the roadway.

In the USSR prefab surfaces for temporary roads began to be developed at the beginning of the fifties. In 1950-51 these surfaces were devised to carry 1000 vehicles of type MAZ-525 (loaded wieght, 46.5 metric tons) per twenty-four hours, laid on a temporary subgrade. The designers* of the pro-

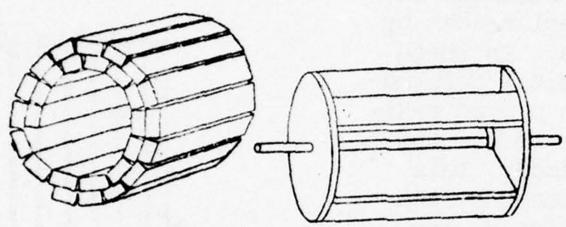


Fig. 182. Prefab artinlated paving surfaces, rolled on a drum.

ject in choosing the principle surface construction schemes strove to simplify the work of manufacturing the elements and their assembly and dismantling. This is especially important in connection with the fact that the designs were meant for short-term use in surfaces for approach roads to excavations, foundations and other analogons units. Roads in these conditions have short turning radii, significant grades and are built in cramped conditions.

For maximum ease of surfacing it was projected as a track-type construction (fig. 183). Considering the great demands for work capacity an independent surface was planned for each direction of traffic. The width of the wheel track was 1.54 m, claculating the wheel width of the MAZ-525 at 0.94 m, and two spare strips along the edges at 0.3 in each (considering the operating experience of lighter vehicles, for which the size of each such strip is 0.2 m).

To prevent the vehicles from driving off the surface a set edge was stipulated measuring 0.3 x 0.2 m. The distance between the axes of the wheel tracks in the plan was approximately equal to the distance between the center points of the rear twin wheels of vehicle MAZ-525. This also specified the median gap at 0.56 m.

(*A.M. Kriviskiy, A. H. Volkov, I. A. Zolotar', A. M. Smirnov)

The length of a slab is set according to the productive capabilities of mobile cranes for laying and dismantling the surface and the limits of transporting the slabs in the most common motor vehicles without a trailer. The given conditions are staisfied by slab lenght of 3.5 m. weighing 3 metric tons. Beneath the slab joints a placing of crossbeams is provided to distribute pressure in the joint zone over a large foundation area and reduce the soil's accumulation of precipitation, which can lead to the disarrangement of the whole surface.

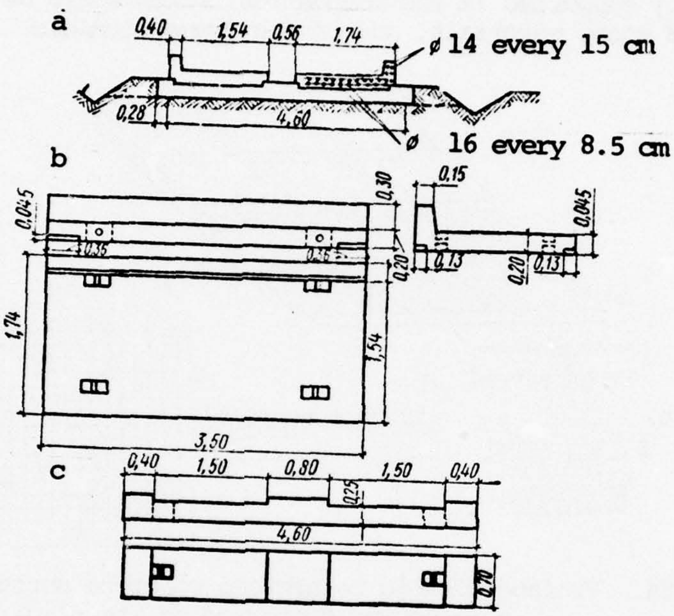


Fig. 183. Construction of a prefab-reusable reinforced concrete surface under heavy loads.
a) cross profile of the road b) an element of the wheel track
c) cross beam

In the crossbeams cutouts and lugs are arranged fixing the position of conjugate elements and excluding the psssibility of their mutual displacement in the plan. The cross beam sinks into the soil, while the wheel track slabs are laid on its graded surface; if the cross beams are laid directly on the ground, then a well leveled underlying layer of sand is arranged between them, supporting the wheel track slabs.

The slabs and cross beams are designed according to Prof. B. N. Zhemochkin's method as bems on a resilient foundation. Reinforcement of the lower area of the slabs is produced by round pivots 16 mm in diameter installed every 8.5 cm. In the bottom area of the slab 8 such pivots are set. Upper reinforcement in the slabs equals 40%,

while in the cross beams it is 50% from the bottom. The remaining reinforcement is attached constructionally.

Simultaneously, continuous prefab reinforced concrete surfaces were devised in the form of slabs measuring 2x2 in. along frames of 6x6 or 6x4 in. with borders along the lower edge of the slab perimeter (fig. 184). The slabs, projecting below the borders, were laid on reinforced concrete frames in which special slots were arranged for their placement. The top of the reinforced concrete elements of the frames was located in the plane of the foundation. Consequently, the slabs were simultaneoudly supported in the foundation, which would be the ground or a layer of stone materials, and on the frame elements.

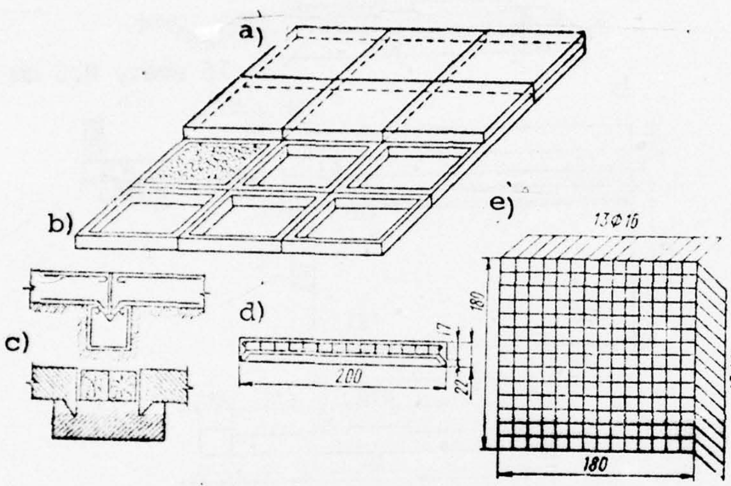


Fig. 184. Prefab-reusable reinforced concrete surface made from a frame and supported on its slabs:
a) general view; b) detail of the slab joint; c) variant type of slab joint; d) cross-section of a slab; e) scheme of slab reinforcement.

A variety of such structures was devised whose support plane has small ribs with a triangular profile. These ribs are located at right angles along longitudinal and trnasverse directions of the slabs. They guarantee a more reliable bond of the slab with the foundation, especially in the middle part.

The surface is designed according to the hypothisis of resiliant semi-space on soils characterized by stress-strain moduli of 100 to 150 kg/cm^2.

Several variations of continuous surfaces were worked out, distinguished by size and type of reinforcement. Basic data on these structures are set forth in table 50.

Next to be developed were structures of prefabricated reinforced concrete track-type slabs*. Various structures were

*Designers of these structures is Candidate of Technical Scineces, A. V. Yakovlev.

TABLE 50

Type of slab	Dimensions in meters	Weight in Metric Tons	Material expenses for one sq. meter of surface		Maximum load on twin wheels, in metric tons.	Type of foundation
			concrete m^3	steel kg.		
I	2x2x0,17	1,7	0,17	16,5	16	On artificial foundation, strengthened with cross beaming and side ledgers.
	2x2x0,17	1,7	0,17	11,5	10	On artificial foundation.
					5	On weak local soil
II	3x1,75x0,15	1,9	0,15	14,5	10	On artificial foundation
					5	On weak soil
		1,7	0,15	10,0	5	On artificial foundation
					3	On weak local soil
		0,85	0,13	11,0	4	On artificial foundation
III	1,75x1,5x0,13				3	On weak local soil
		0,85	0,13	7,5	3	On artificial foundation
					2	On weak local soil
		2	0,15	14,0	10	On artificial foundation
IV	3x1,75x0,18		0,15	11,1	5	On artificial foundation
					3	On weak local soil

NOTE: Types I, II, III include slabs with edges along the perimeter and type IV, slabs with a small-ribbed support surface.

elaborated as presented in figure 185. These surfaces were designed without crossbeams. Material expenditures and basic measurements are displayed in table 51. Table 51 basically shows (fig. 185, b) lattice slabs (except types P-Ya, P-1 and IV - 1). Of these, type P received the most practical into widespread use. For laying track slabs around curves trapezoidal continuous slabs were designed, designated in the table by the added notation 1. These structures are laid with there long side crossways to the traffic lane. The wheel track slabs adjoin them. In this fashion the given slabs are laid for curves in the plan. Besides the trapezoidal slabs, table 51 notes the following with additional signs: P-N, a slab of stressed concrete and P-Ya, a slab having cells in its lower part (on the support surface side)

instead of teansverse aperatures (fig. 185, a) slab support surface in both lattice and all structures improves the conditions of adhesion with a soil or sand foundation. Concrete in the slab is unevenly distributed. In places where reinforcement pivots are located, concrete fills in all the cuts in the slab, forming a continuous diaphragm, while in the places

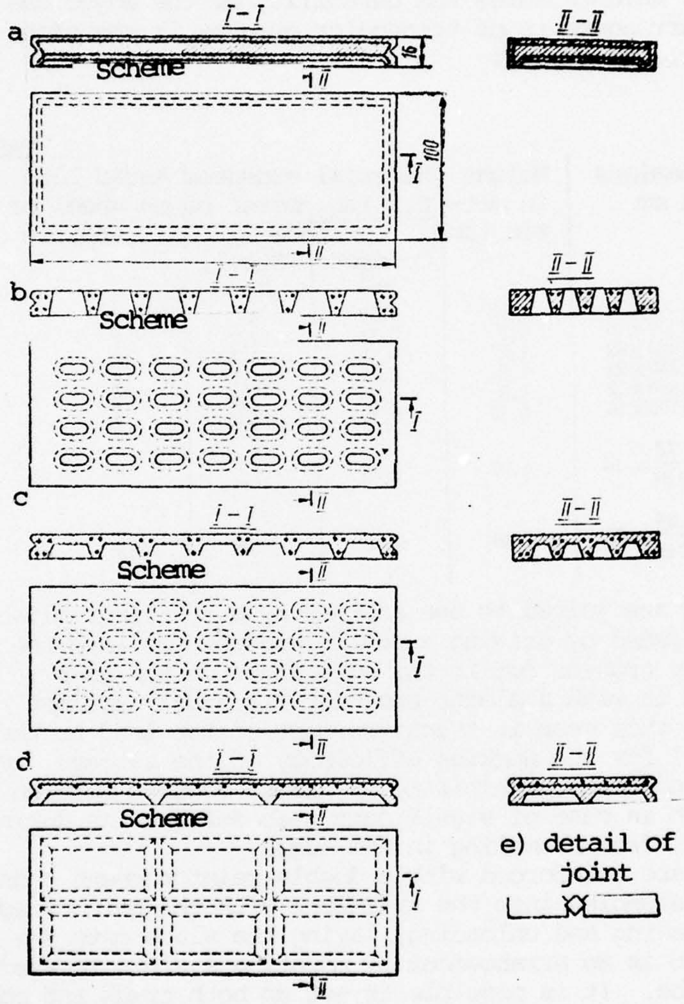


Fig. 185. Slab structures of track surfaces:
a) continuous slab with edge on perimeter; b) lattice slab; c) cell slab d) caisson slab; e) detail of joint.

with no reinforcement it gets partially or entirely cleared away. With a relatively small expenditure of concrete per square meter one can succeed in maintaining a rather significant slab height. Moreover, stronger reinforced concrete diaphragms are located around the slab perimeter, as if to form an encasing. These contain more concrete and reinforcement than the middle cuts, which assures the durability of the edges and covers and makes possible arrangements of triangular grooves in the edges of the slabs without noticeable weakening.

TABLE 51

Type of slab	Dimensions in cm	Weight in metric tons	Material expenses for 1sq. meter of surface		Rated load on wheel of vehicle
			Condrete m^3	Steel, kg.	
I	250×100×14	0,63	0,10	9	4
II	250×100×16	0,7	0,11	12,2	7
III	300×125×22	1,5	0,16	13,4	18
IV	300×150×22	1,8	0,16	15,4	18
P-N	600×100×12	1,3	0,08	7,4	7
P-Y	250×100×16	0,75	0,12	12,2	7
P-1	$320 \times \frac{73}{110} \times 16$	1,07	0,16	15,2	7
IV-I	$450 \times \frac{80}{115} \times 22$	2,10	0,22	13,8	18

The slabs are joined to one another by a resilient-pliable joint (fig. 185, e), accomplished by driving a square wooden beam into the cavity formed by the triangular grooves cut in the edge faces of the slabs. The wooden beam is hammered in with a sledge and must fit snugly against the faces of the grooves. In this case it transfers part of the load to the adjacent slab which speaks well for the working efficiency of the surface. Besides this, such a beam excludes the possibility of direct contact between the adjacent structures, which in case of significant slab deformation during operation prevents concrete from crumbling in the edges.

The slabs are reinforced with a double reinforcement consisting of two welded meshes, assembled into the framework with the help of special light trusses. For loading and unloading, laying the slabs onto the surface and dismantling there is an arrangement of mounting eyelets located on the side faces of the slabs. It is possible to set up both track and continuous surfaces from these design elements.

The most active application of lattice structures is for the construction of logging roads, where the quantity of reinforcement while preserving the same geometric dimensions was first set at 16 kilograms per square meter of slab.

Reinforced concrete slabs with a lattice structure were first applied on the Khaynozersk logging road* in the Arkhangelsk district. Construction was begun ln 1955. Since the surface on this road was laid on a specially built soil subgrade and on sand foundation it works satisfactoruly. In analogons conditions, that is, with sufficient foundation durability and guaranteed drainage, the structures work satisfactorily. However, drainage can only be assured with great difficulty due to the water permiability of the surfaces, while a capital subgrade is not set up for temporary roads.

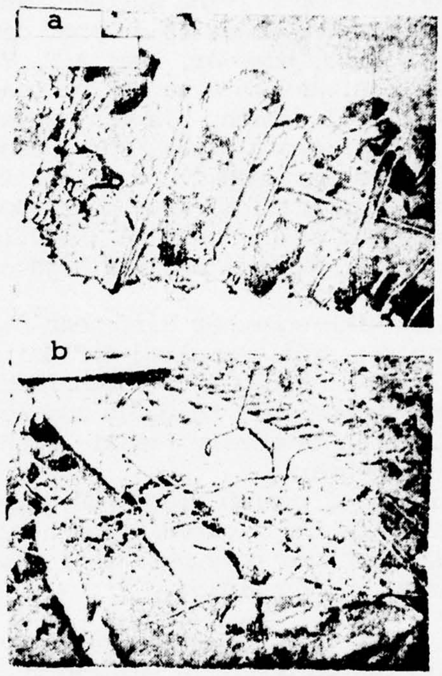


Fig. 186. Destruction of latticed reinforced concrete slabs: a) destruction of the middle portion of the slab; b) complete destruction.

Operating practice of latticed slabs in track surface temporary logging roads disclosed a series of deficiences in these structures. Their strenght was not always up to operational loading. Fissures in the slabs, carried up to the

*Construction was carried out by one of the subdivisions of the building organization headed by the handbook's authors, V.M. Mogilyerich and S.V. Konovalov.

driving surface, cause an increase in the dynamic action of the load, and in several cases lead to the destruction of the concrete into sharp edges fringing the fissures. Then the concrete falls apart and bares the reinforcement. Fig. 186 shows examples of the destruction of separate slabs as a result of their operation under heavy conditions. Moreover, the visual perception of the latticed surface quickly tires drivers. In the fall, moi-ture collects in the fissures and freezes into protruding knobs, making driving on these surfaces more difficult. Further research on reinforced concrete slabs for prefab track surfaces led to redesinging of such slab structures with a continuous t op driving surface, which meets the real conditions of their work under rated loads to greater degree.

It is appropriate to note, however, that A.V. Yakovlev's latticed slabs proved successful nonetheless, and on a number of roads with good operating conditions justified their application. In many ways they exceeded structures that mechanically copied floor slabs from industrial-civil buildings. Thus, for example, road slabs designed in trust no. 102 of Glavleningradstroi (Chief Leningrad Building Organization) were continuous, permanently cut with flat support, driving and side faces. A 3x1x0.18 m slab weighed 1.4 metric tons with reinforcement expenditures as high as 27 kg per square meter of slab.

Analogons slabs only with somewhat different dimensions and a reduced quantity of reinforcement are sidely applied for building in Moscow. Such slabs, having an excessively high rigidity which leads to an increase in bending movements, demand exceedingly thorough and level laying on the foundation, not always feasible on temporary roads. With poor adhes ion to the foundation they quickly fall apart.

Operational experience of prefab slabs for temporary roads has shown that it is appropriate to keep the figured support surface and joint arrangement of slabs as long as there are no substantial changes in the techniques and technology of temporary road building.

33. SLAB STRUCTURES MADE OF COMMON AND PRESTRESSED REINFORCED CONCRETE

In the present paragraph slab structures of track and continuous surfaces for temporary roads are examined both as they are already in use for roadbuilding and as they are found in the design and testing stage.

In the Moscow Automobile-Road Institute (MARI) slab structures for prefab track surfaces made of reinforced concrete, prestressed concrete, sand concrete and structural lightweight aggregate concrete* and being worked out for temporary road surfaces. The following principles are observed in the construction and design of slabs:

*Designer - Candidate of Tech. Sci. S. V. Konovalov

1. Slabs are laid onto the foundation without cross beams and underlayment, because these substantially increase material expenses and overall weight of the prefab surface. Laying crossbeams or underlayment of whatever sort calls for significant expenditures of manual labor.

2. The support surface, transverse and longitudinal cuts of the slabs should be figured. The narrow stripes of crisscrossed diaphragms on figured slabs easily overcome the unevenness of soil foundations or a sand underlayer, sinking into them. The result of this is good support for the slab on its foundation. The evenness of the surface and its bond to the ground are improved.

Besides this, figured outline slabs, compared to continuous slabs of even strength, weigh less, and for equal weight have greater structural height, which creates better conditions for their reinforcement and the placement of joint arrangements.

With a continuous support surface any unevenness in the foundation causes poor slab support. As is well known, in this case the carrying ability of the surface is noticeably reduced and a stable position for the slab on the wheel tracks can be achieved only at great expense.

3. The upper longitudinal reinforcement is set according to calculation. The quantity of reinforcement, in connection with an increase in the dynamic coefficient during the wheel passage over the slab joint, is roughly equal or slightly exceeds the quantity of lower longitudinal reinforcement. A protective layer of concrete for the upper reinforcement is set at no less than 2.5 cm, which guarantees dependable work by the driving surface of the slabs.

4. Structure of the slabs should take into account the manufacturing technology.

Slab structures designed at MARI can be divided into two categories: for laying on subgrade, characterized by a soil stress-strain modulus of 80 to 100 kg/cm^2, and for laying on a soil surface with guaranteed water drainage and characterized by a stress-strain modulus of 60 to 80 kg/cm^2. All these slabs are designed for the loads of vehicles MAZ-501, MAZ-200, and Kraz-214.

Figs. 187-190 show slabs meant for surface layout on a subgrade. They are laid on a sand under layer with a thickness of 15-25 cm (in the second dlimatic zone).

Fig. 187. depicts a cellular slab of reinforced concrete.

The smallest measurement of the upper layer of reinforced concrete is composed of 40 mm, which permits the application of concrete on aggregate up to 40 mm when using a round casing form for forming cells. In this structure the allowance for placing reinforcement gird pivots is $\pm$ 20mm. Consequently, the slab structure allows its manufacture not only in factories with any type of technology but also under field conditions. Locating the pivots closer together in the edge zones of the slab follows the demands of the design.

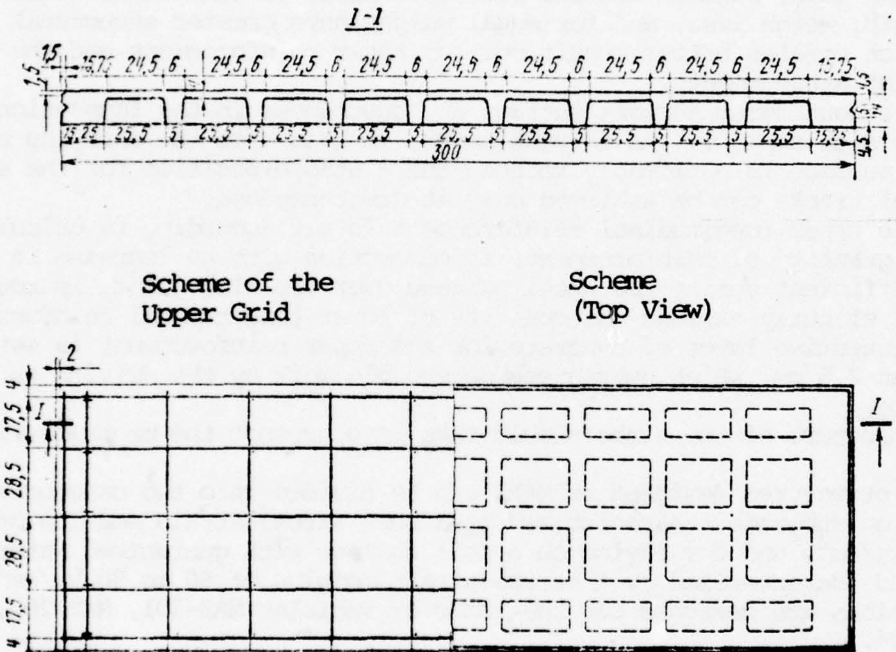
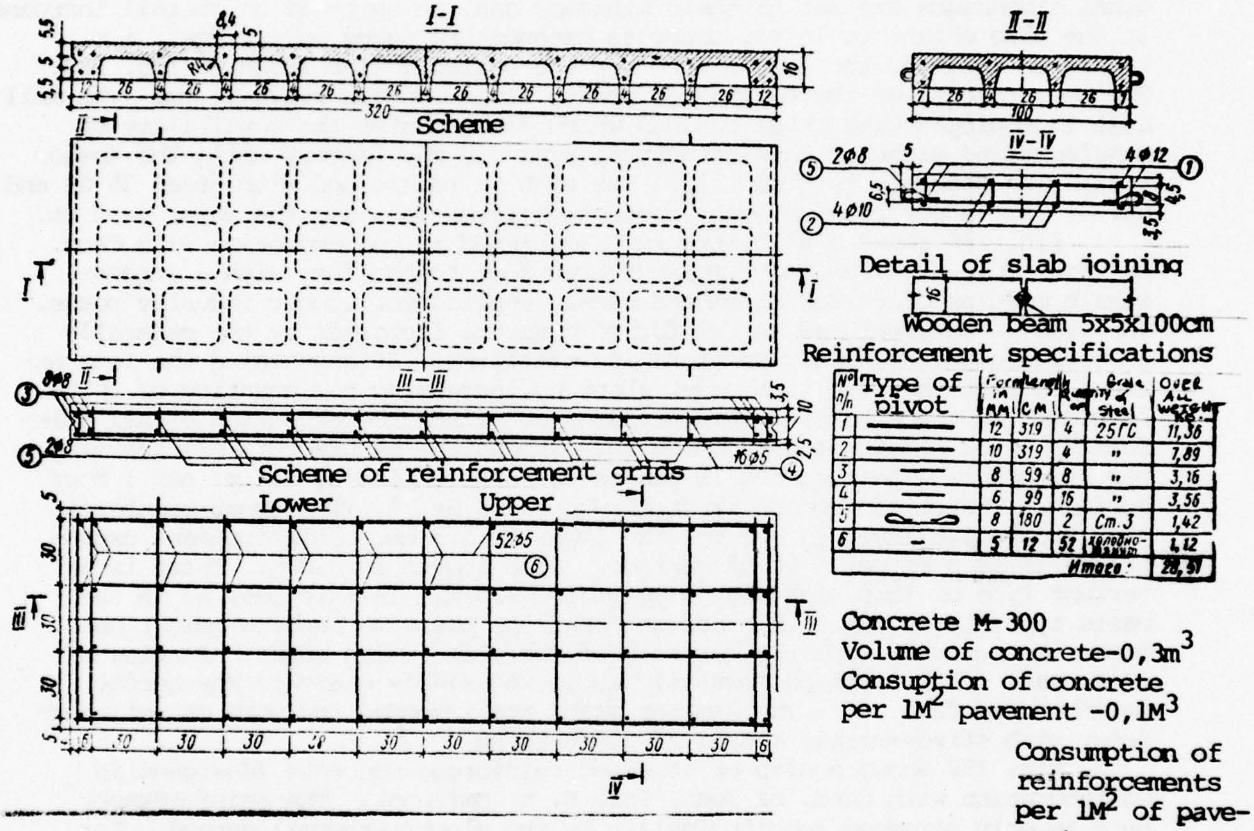


FIG. 187. Cellular reinforced concrete slab.



Reinforcement specifications

№ п/п	Type of pivot	Form in мм	Length см	Quantity	Grade of Steel	Over all weight kg.
1	▬▬	12	319	4	25ГС	11,36
2	▬▬	10	319	4	"	7,89
3	—	8	99	8	"	3,16
4	—	6	99	16	"	3,56
5	∞	8	180	2	Cm.3	1,42
6	-	5	12	52	холодно-тянутая	1,12
					Итого:	28,51

Concrete M-300
Volume of concrete-0,3m^3
Consuption of concrete per 1M^2 pavement -0,1M^3

Consumption of reinforcements per 1M^2 of pavement.

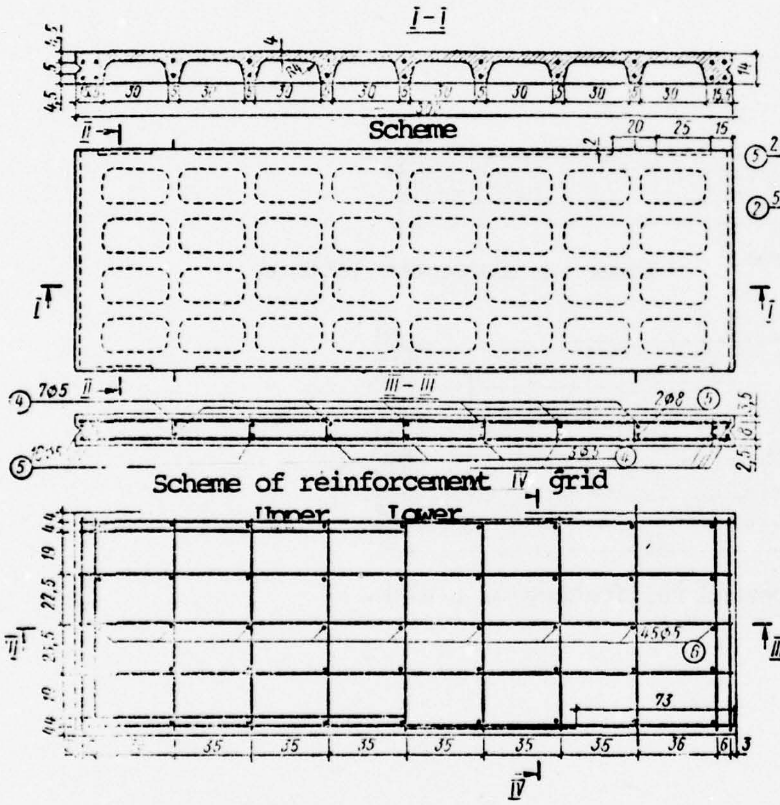
FIG. 188. Reinforced concrete slab intended for manufacture by continuous-rolling mills.

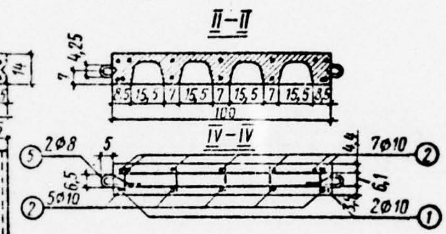
The slab is symmetrically reinforced. Steel of (soviet) grades St. 3 and St. 5 is applied for reinforcement protective layer is 2.5 cm, the lower is 1.5 cm. The concrete is (soviet) grades 250-300. The slab can be manufactured from light or heavy concrete and used over foundations characterized by a stress-strain modulus of 80 to 100 kg/cm^2.

Fig. 188 presents a slab designed for manufacture on a continuous rolling mill by N. Ya. Kozlov. In light of the fact that factories disposed of such mills are enterprises of with a high degree of industrilization, automation and culture of production, the measurements of transverse and longitudinal diaphragms are set to their minimum, and, in spite of an overall increase in the slab ehight to 16 cm, concrete expenditure takes only $0.10m^3$, i.e., it proved equal to the expenditure for the cellular slab shown in fig. 187. The measurements of the casing for cavity formation are 26x26x11 cm. The mill belt is equipped with these casings which demonstrates the possibility of manufacturing slabs of this structural type in any factory using the Kozlov mill. The concrete is grade 300. The slab is reinforced with steel 35 GS and St. 3. The upper reinforcement protective layer is 3 cm, the lower is 2 cm.

Fig. 189 shows a slab structure (designed in collaboration with Cand. of Tech. Sci. B. N. Smirnov) meant for work on foundations with a stress-strain modulus of 80-100 kg/cm^2 and widely applied for lumber industry roads. The slab is manufactured in reinforced concrete factories by the generally accepted technique, i.e., on vibration platforms. Strengthening the long extreme edge of the slab is brought about by increasing the quantity of reinforcement in these bands. This decision permitted the execution of all hole-forming cores simultaneously which strengthens the manufacture of sheathing for the slabs. The concrete is grades 250-300, expending 0.1 m^3 per 1 m^2 of surface. The reinforcement is steel St. 5 and St. 3. The upper reinforcement protective layer is 2.5 cm, the lower is 1.5 cm. Reinforcement expenditure is 10.9 kg per 1 m^2 of surface. Slab length is 310 m. There is a variant type of this slab with a length of 2.0 m. In this one, as in the basic type, it is taken into account that the positive bending moment goes down substantially from the quarters of the slab to its edges. In view of this, part of the reinforcement pivots in the slab's quarters may become detached and fall off. The 2 meter slabs are intended for work on soil surfaces with stress-strain moduli of 60-80 kg/cm^2.

Fig. 190 shows a slab of stressed-reinforced concrete (designed in collaboration with Cand. of Tech. Sci. B. N. Smirnov). The reinforcement here is only stressed longitudinally, by the electro-thermal method. For this goal steel of USSR-standard 8480-63 with a diameter of 8 mm or class A-IV is used. In the first case the reinforcement expenditure is reduced by 2 kg per meter of slab to 6.8 kg/m^2. All hole-forming cores have the same dimensions. The slab is simple in manufacture, and its significant length reduces the number of joints in the surface.





Reinforcement Specifications

Number of	Type of pivots	MM	Length in cm	Quantity of	Steel	Overall weight in kg
1		10	150	2	Cm.5	1,85
2		10	296	12	Cm.5	21,80
3		8	55	10	Cm.3	3,82
4		5	36	10	холодно-тянут.	1,48
5		8	180	2	Cm.3	1,43
6		5	12	45	холодно-тянут.	0,83
					Итого:	31,21

Concrete: M-300
Volume of concrete: 0.3M Expenditure of concrete per 1 m^2 of surface: 0.1M

Slab area: 3m^2
Expenditure of reinforcement per 1 m^2 of surface: 10.4 kg.
slab weight: 760 k

FIG. 189. Reinforced concrete slab, intended for manufacture in specialized factories.

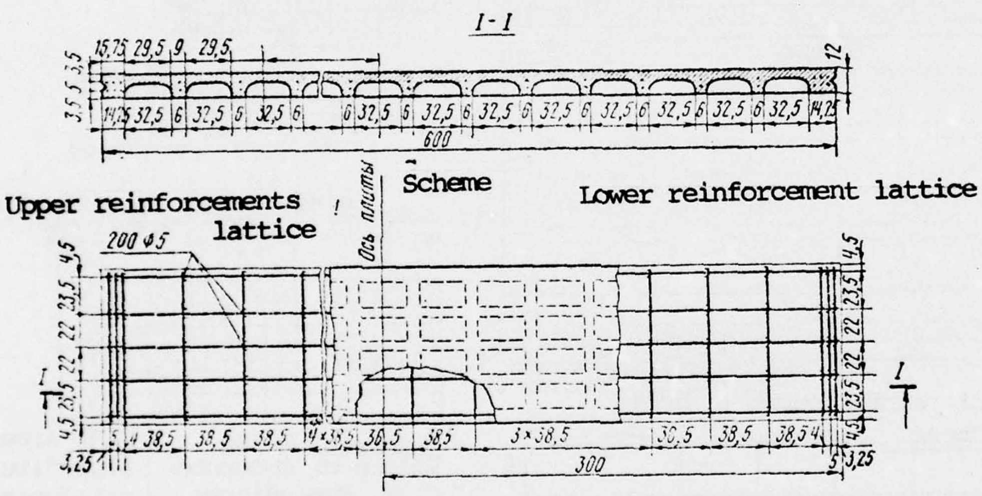


FIG. 190. Stressed reinforcing of a slab.

Stressed-reinforced slabs, apart from the type shown in fig. 190, have a trapezoidal form and a length either 6.0 m or 3.0 m. These structures are the most hardworking and for practical purpose can withstand any traffic. The stressed reinforcements method is the most long-range for road surfaces, including prefab types. The most effective type for reinforcement expenditure are wire reinforced slabs which, due to the possibility of stressing high tensile wire by the electro-thermal method, will in time receive the most widespread use.

Besides the aforementioned slabs for temporary roads, in several organizations other structures are also being devised.

Fig. 191 illustrates an L.F.A slab (Leningrad Order of Lenin Forestry Academy) for prefab track track-type road surfaces which can be built on graded ground with a stress-strain modulus of 40-60 kg/cm^2. The slabs have seen some distribution for logging roads, and because of this the state standard handbook of the USSR, GOST 15466-70, "Reinforced Concrete Slabs for Logging Vehicle Road Surfaces", devised by Ts. N.I.I.M.E. and M.A.R.I. was confirmed and introduced. In different conditions their application is limited by the large expenditures of reinforcement needed (27-30 metric tons per kilometer of surface).

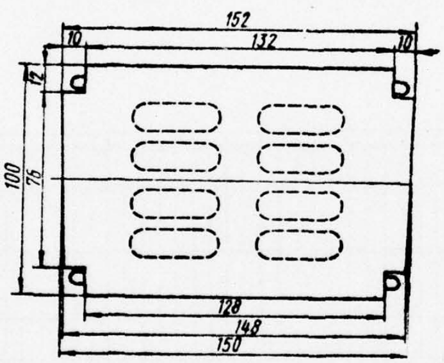


FIG. 191. Reinforced concrete for laying directly on soil surfaces.

The slabs shown in fig. 189 (length of 3.0 and 2.0 m), 190 and 191 are indcluded in the GOST handbook in their rectangular variant type (i.e. entirely corresponding to the above working drawing) and trapezoidal type. Trapezoidal slabs are perfect ananlgnes of the rectangular type with the sole difference that they have a different side length. Thus a rectangular slab 6 m in length (fig. 190.) is marked PN-6, while the trapezoidal type with side measurements of 6.03 m and 5.97 m is marked PTN-6. The rectangular slab (fig. 189) is marked P-3 and the same trapezoidal slab, with side length measurements of 3.015 and 2.985 m is marked PT-3. The same slab in trapezoidal form 2 meters long is marked PTV-2 while the L.F.A slab (fig. 191) is marked PTV-1-1.5.

Apart from the slabs we have examined made of reinforced concrete and stressed-reinforcement concrete for prefab surfaces on roads built for logging and other track-type roads, temporary

road slabs applicable to urban conditions are used.

Fig. 192 shows a stressed-reinforced slab by NIIMosstroy, earmarked for continuous prefab surfaces on construction projects of city industrial-civil building.

The above structure was worked out on the basis of comprehensive testing of slabs of this structure on a resilient foundation and on the basis of experience data on the operation of both these slabs and slabs PDG-1.5x6S and PDG-2.0x6S which have initial characteristics close to the slabs discussed. The PDG slabs were developed under load N-18 by engineer K.D. Zhukov et al. and received well-publicized distribution for automobile roads where they operated successfully under conditions close to those calculated for them. However, PDG slabs proved impractical for application on temporary roads. The upper reinforcement of these slabs, calculated for permanent road conditions cannot guarantee the necessary

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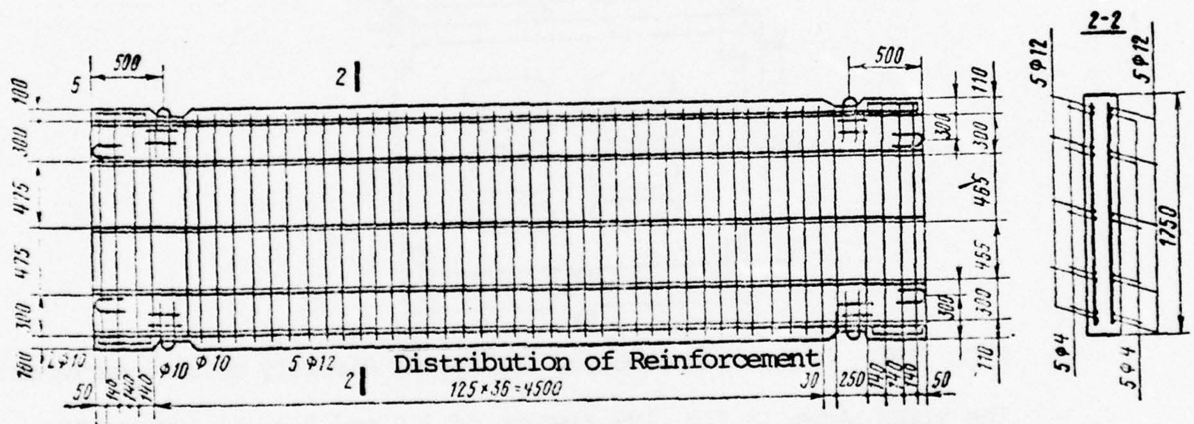


Fig. 192. Stressed Reinforced Slab.

durability for the operation of temporary roads. Transverse cracks arise in them since weakening of the foundation under the slab joints of temporary roads occurs due to its getting wetter than the center section of the slab. For this reason the area of the slab's upper reinforcement, as operational practice with prefab surfaces on temporary roads has shown, should be equal to or greater than the area of the lower of the lower zone. The area of the lower and upper reinforcement grids is defined by calculation, as shown in chapter II. Besides the transverse cracks, destruction of concrete takes place on the driving surface from having heavy machinery drive on and off the surface.

The slab shown in fig. 192 does not have the described inadequacies since its upper reinforcement is strengthened, and its area made equal of the lower reinforcement. This decision (applicable to the given slabs) makes using them from both sides possible. The number of repeated applications of slabs increases in this case, and the structure's economic effectiveness grown. In the example we have taken of a slab the transverse direct is divisible by half the width of the traffic strip. Under certain circumstances it guarantees the possibility of the leaving the slabs as the foundations of permanent roads. Under calculated conditions this measurement is advantageous since with a width of more than 2 m. the slab might be carrying 4 rather than 2 vehicle wheels, which would lead to a substantial increase in reinforcement expenditure. Considering that we are speaking of continuous rather than track-type surfaces, the general savings of reinforcement material for a slab width of 2.0 m could go as high as 2 kg per square meter of surface.

TABLE 52

Basic Indeces	Slabs designed by N I I Mosstroy	Slabs PD-36-12 PD-32-12
Reinforcement	Stressed in the longitudinal direction	Unstressed
Metal Expenditure, kg/m^2	11	16
Concrete Expenditure m^3/m^2..	0,142	0,162
Grade of concrete, kg/cm^2...	400	300
Thickness, cm	14	16
Dimensions in the scheme, m .	6,0x1,75	3,0x1,2; 4,0x1,2
Area	10,5	3,6÷4,8
Possible width of roadway, for requirement of 3.5 m ...	3,5	3,6
Overall extent of seams for one km of one-lane road;	1583	3003
Including transverse seams	583	1008

34. STRUCTURES OF PREFABRICATED SURFACES MADE OF METAL, WOOD, SYNTHETIC MATERIALS, FIBERS AND RESINS

In many cases prefab surfaces for temporary roads are composed of the same materials as prefab surfaces of the permanent type. But metal, wood, various synthetic materials, fibers and resins are applied for the manufacture of prefab and prefab- reusable surfaces as well. Metal prefab surfaces are very general-purpose structures. Metal allows temporary road surfaces to be of flexible or rigid, continuous or track arrangements. Such surfaces have been devised in the USSR and many countries throughout the world. Basic advantages of metal prefab surfaces are their relatively light weight and repeated reusability.

Flexible surfaces have been designed, tested and formed a certain distribution in the shape of wire mesh, laid by mechanical means onto track or continuous surfaces.

The track surface consists of two wheel tracks one meter in width and a median gap. Continuous surfaces are usually set up to be one-lane, 3 meters wide. Wire mesh is applied to guarantee passage over sandy areas or as an inti-skid device on soild overwetted to a small depth. A single mesh can guarantee passage for cars. Passage for truck traffic requires overlaying mesh in three layers with additional layers of plank, fibers or other materials.

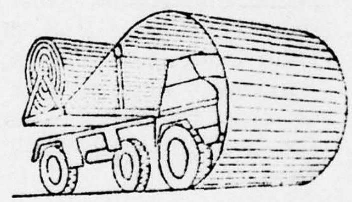


FIG. 193. Laying a flexible metal surface on a temporary road.

The steel mesh of a flexible surface is made up of wire with a dimeters of 3 to 3.5 mm, with cell dimensions of 3x3 to 7.5x7.5 cm. The weight of one km of track surface may go as high as 12 metric tons. Cables with a diameter of 8 mm are passed along the edges of the surface. Vehicle traffic on the mesh is permitted laying brushwood, planks or filling in with soil. Traffic can be implemented for a short period of time (up to two or three weeks.) The building rate for such surfaces with normal laying reaches 200 m per hour, mechanically, 600 m per hr.

Continuous flexible surfaces have also found application. Fig. 193 shows a sketch of laying this type surface as used in England. The surface consists of a strengthened aluminum band and is transported on a truck with a trailer. One vehicle can carry 55 m of such road. The surface is intended for automobile traffic. The surface elements are stamped out of alloy VA-25R. One square meter of the structure weighs 20 kg. The method of laying with the help of a truck shown in fig. 193

is most widely used for all type of flexible surfaces.

Rigid surfaces are imposed of slabs usually in the form of corrugated steel or flat sheets with a thickness of 1.5 ÷ 2.0 -4.0 mm, bordered along the perimeter, sometimes further strengthed across their area with profiled metal. As a rule such surfaces are track-type with slabs joined at the edges by various locking devices. The weight of one km of continuous surface made of such elements, independent of perceptible load, varies from 17 to 300 metric tons. Both rigid and flexible metal surfaces are widely applied for military roads (3). Because of their low weight, good operational qualities and especially their ability to be relaid many times metal surfaces are finding wide application for ordinary roads. Thus in the USSR structures of reusable metal slabs designed at the Urals Polytechnic Institute are applied. These structures are meant for use as surfaces on logging roads during the Spring and Fall seasons of bad roads, but operate during the summer period as well.

Metal slabs are manufactured as welded structures of steel plate, with a 4 mm thickness, channels or I-beam n. 14 and corners . Metal expenditure for one km of one-lane surface is 100 metric tons. The surface is designed to work successfully over overwetted heavy dusty loam, characterized by stress-strain moduli of 30 to 70 kg/cm^2 under traffic of vehicle type MAZ-509P with loads up to $22m^3$ of fresh wood. Laying is accomplished over cross beams, and if necessary over lengthwise sleepers as well.

The surface is protected with wheel deflectors laid along the cross beams. A test section of surface was operated without the metal slabs being joined to one another. These slabs have rectangular and trapeziodal configurations in the scheme. Their dimensions are 6x1.0x0.067 m. In the process of operating the surface an increased slab flexibility was discovered on loads approached the joints between them. However, in spite of this, deformities in the surface did not arise.

The coefficient of adhesion between tire and surface independent of surface structure and condition varied within limits of 0.25 for smooth tires to 0.7 for corrugated types. Load truck traffic was carried out at 20 km/hr. For extended grades of over 2% it is recommended to lay slabs with a corrugated driving surface. The slabs weigh 300 kg. 12 slabs are loaded onto a truck at once. Loading the slabs and laying then on the surface was implemented by mobile crane LAZ-690. Laying one km of surface expended 29 vehicle-relays of crane, tractor and truck. Another interesting experiment was the application of steel prefab-reusable surfaces assembled at a rate of one km per 24 hours for four-lane traffic. These temporary metal surfaces have been applied in the Federal Republic of Germany (West Germany) for repairing super-highways. The slab structure consists of cored slabs weighing 4.5 metric tons, 12.25 m.

wide, 2.4 m long, 30 cm high, manufactured from sheet metal 3.5 or 6.0 mm thick. The slabs are laid on a concrete surface over lenghtwise wooden beams which are joined to the slabs with bolts. Structure of the metal surfaces allows the road to overhang on each side by 2.2m on lateral contlevers. In this way metal slabs allow two roadways to be set up, divided and protected by a curb 30 cm high to assure 2 - lane traffic in each direction.

The roadway part of the slab is surfaced with a wear-resistant synthetic adhesion. The surface is calculated for loads fo 30 metric tons. The slabs are layed by self-propelled cranes and joined with the help of steel hoops. They carry traffic up to 50 km per hour. The life expectancy of such slabs under intense and heavy traffic is dèsignated at 10 years for a rough guide. They are used for transporting four-lane traffic laid on the separating strip of a two-lane roadway and the roadside of a wuperhighway.

Prefab wooden surfaces for temporary automobile roads can be flexible or rigid.

Flexible surfaces consists of two wheel tracks. Each strip of this type surface consists of separate mats 10 or 20 m long. The mat is made up of wooden beams measuring from 7x7x100 cm to 15x15x100 cm, with a distance between beams of 3 cm. The beams are made fast to two longitudinal cables 5mm in diameter with staples 8 to 9 cm long. The longitudinal cables have eyelets for fastening the mats to one another. This flexible track surface structure is simple to manufacture and is easily transported and laid. However, such surfaces have low work tolerance and one sntended to pass a limited quantity of automobiles.

A flexible surface of the ribbon type has been designed and tested by the Northern Scientific Research Institute of Forest Industry. The surface is calculated under constant traffic of trucks type MAZ-509 and ZIL-157 with trailers loaded with fresh wood, with a load on each wheel up to 6.0 metric tons. The wooden reusable track surface of the ribbon type (2) is to overcome sections of difficult passage on logging roads with a discontinuous term of operation. Surfaces in the form of tracks are laid directly on rough-graded ground or a brushwood covering of 8-20 cm thick.

Each ribbon (wheel Track) is assembled from separate links 1, joined together with knuckle-joints 2. The link is a wooden panel measuring 12x55(70)x110cm, assembled from treated joists 12x16x110 cm of coniferons or decidnons species. The joists are connected to each other by two metal hoops (yokes) 3 of steel strip 6x60 mm thick

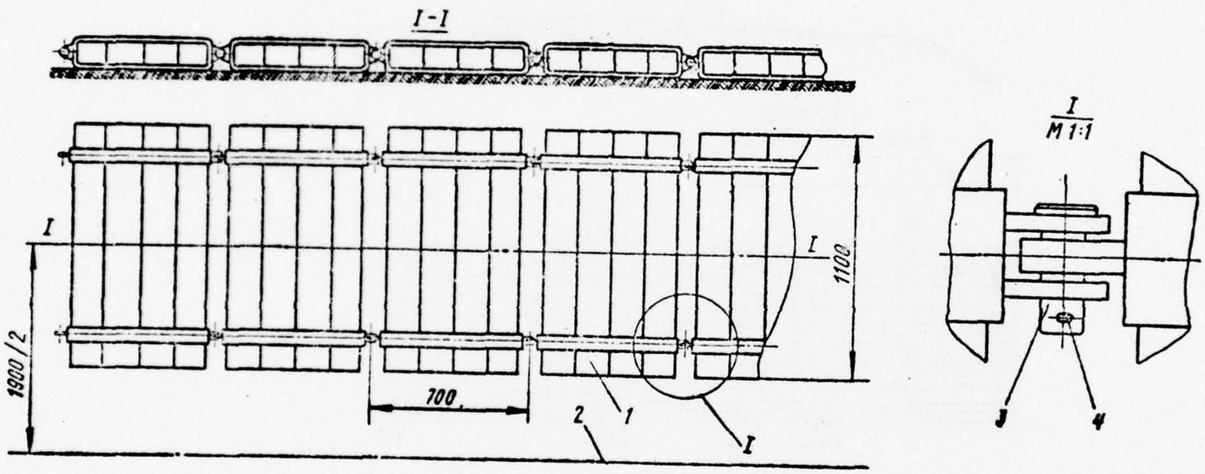


FIG. 194. Structure of a wooden and metal prefab-reusable surface of the ribbon type.

with openings under the studs having a diameter of 20 mm. A general view of the surface is shown in fig. 194.

The short length of the link (55 or 70 cm) enables its tight fit into the grooved or brush and also leads to a reduction of better than two times in bending moments for these links compared to reinforced concrete slabs 2.5m long. Ribbons are distinguished for their ease of manufacture. For one kilometer of one-lane track surface 240m^3 of wood, 25.2 metric tons of strip steel and 2.3 metric tons of round steel are expended. The weight of one meter of ribbon makes up 87 to 104 kg, with a unit weight of wood of 600 to 800 kg/m^3 correspondingly.

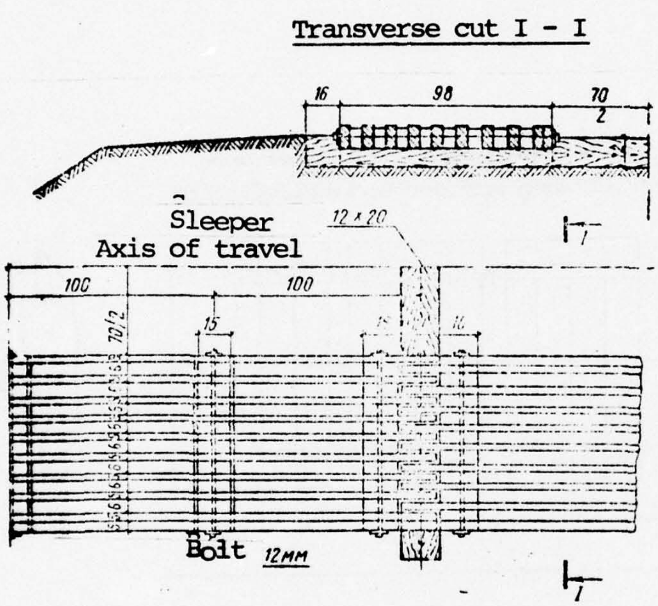


Fig. 195. Lattice wooden plank surface.

Rigid wooden prefab surfaces are made up of plank, beam and timbered panels and links. Plank panels come in two types, forming the driving surface with either the wide or narrow side of the planks. When they are located with the wide side up the panel is assmebled from 6 planks 16 cm wide, 5-6 cm thick and 3.0 m long. The planks are assembled into panels by attaching them with nails to cross boards set 0.5 to 0.55 m apart. The first plank is set 0.25 from the edge of the slab. The weight of one slab varies within limits of 120 to 150 kg. Vehicle type ZIL-157 can transport 40m of road surface.

When the planks are set up on the narrow side (on the rib) the carrying ability of the surface rises substantially. Boards 5-6 cm thick are put together on the slab with 6 cm gaps. They are joined with bolts in the transverse direction, set one for every one meter of slab length.

The joining is made by joining the edges of contiguous slabs in the cross-beams, placed only below the junction.

Timbered panels are manufactured from round timber 14 to 16 cm. in diameter trimmed on two edges. These panels weight 300 to 350 kg. Timbered and beam panels are assembled with bolts or splines. Their dimensions are 3.5 (4.0) X 0.14m.

Rigid prefab surfaces are assembled in links of 2 panels already put together on crossbeams and fully prepared for laying on the surface in order to increase the productivity of crane equipment.

At the present time in the road-surface laboratories of the Central Scientific Reasearch Institute of Mechanization and Energy of the lumber industry (Ts. N.I.I.M.E.) they are devising wooden beam panels 5.0m long with edges strengthened with profiled metal. Such a decision substantially increases the turning ability of wooden panels.

The surface is figured out for the loading of logging land-trains of the MAZ and KrAZ types, and consists of separate panels joined together with splines.

Surfaces on temporary roads are also made up of synthetic materials, fibers and resins. Several synthetic materials put out by industry have sufficiently high indexes of durability for use in structuring prefab surfaces. At the same time they are lighter than many other materials.

The characteristics of several materials are set forth in table 53.

TABLE 53

Materials	Specific (volume wght) T/M^3	Elevation: Stenght line PT/cm^2	Elevation: Specific strenght	Compression: Strenght line	Compression: Specific strenght
Steel	7,85	4000	510	4000	510
Duralumin	2,8	4400	1570	4400	1570
Concrete M300	2,2	30	13,6	300	136
Pine	0,6	940	1565	400	668
Wood laminated plastic	1,3	1600	1230	1300	1000
Bakelite plywood	1,1	1200	1040	1100	870
Sdam plastic	1,9	4000	2100	4000	2100

According to its specific durability, i.e. by durability related to specific or unit weight of the material, synthetic materials exceed steel, wood and duralumin. As a result light and sufficiently strong surfaces can be created.

At the present time, taking the volume of production into account it is most practical to manufacture prefab surface slabs from bakelited veneer.

Surfaces of this material, glued or joined with bolts to cleanly squared boards of coniferous wood have been designed, manufactured and successfully tested under production conditions. Their weight for one ton of single-lane track-type surface varies in the range of 80 to 100 kg. The surfaces are calculated for the passage fo heavy and intensive automobile traffic.

Fiber and resin surfaces are most often applied abroad. Coarse canvas, sacking, tarpaulin or a jute subgrade saturated with bitumen are intended to assure short term thoroughfare. On a well prepared earth roadbed such a surface can withstand loading of 7 to 17 metric tons. The earth roadbed shoudl be well packed, corrigated and if necessary reinforced as well. If the earth roadbed is poorly prepared and insufficiently strong the surface will quickly be put out of operation.

Fiber surfaces are delived in rolls and laid in lenghwise overlapping strips by special roadlaying devices on trailers hitched to trucks. The surface is formed from two layers of fiber glued together. A strong glue bond is obtained only after a sulvent of the gluing substance has partially evaporated, which usually requires 2 to 4 hours. The surfaces can be used in temperatures of +10 to 37° C. Seams are spread with bitumen.

Resin surfaces ahve been applied in recent years on temporary roads (test sections).

35. Building Technology of Prefabricated Surfaces for Temporary Roads.

The following demands are made on surfaces of reinforces concrete slabs.

On straight sections of the road, slabs of adjacent wheel tracks should be laid on one level; a deviation in height between them should not exceed 5 to 10 mm.;

The width of the gap between tracks is taken independently of the vehicle types using it; deviation from the given dimensions should not exceed 10 to 20 mm;

The top surfaces of adjacent slabs in one wheel track should be located on one level; the rise between two neighboring slabs should not be more than 5 mm; as an exception this tolerance is sometimes increased to 10 mm;

For creating the joint arrangement slabs shoudl be laid with a clearance of 10 to 15 mm.

Laying the slabs on the surface is accomplished by mobile cranes of special slab-layers type DUP-1 or DUP-2, while loading onto vehicles is done with mobile cranes.

The most widely used method for arranging a surface of reinforced concrete slabs is "push" laying. The motion of the vehicle with the slabs is

carried out along a ready surface in this case. The mobile crane moves in reverse (there are also set-ups for forward crane motion) along a prapared foundation or surface and stops with its back wheels 1.0 to 1.2 m. from the end of the surface. The method of motion for the vehicle with slabs depends on the width fo the subgrade and the number of lanes on the road under construction. There are two approaches possible for the vehicle with slabs: along the ready surface ro on a second track. If the vehicle is moving along a second track it goes in forward gear and stops 3 to 4 m. away from the mobile crane in the direction of construction. Having stopped the crane and truck in the necessary position, the worker hooks up the slab in the bed of the truck by diagonally located installation, after which the crane moves it to the spot where it is to be laid.

Fig. 196. Slab Layer. TZNIIME for one time laying of two reinforced concrete slabs in a pavement.

From a singel stopping point the crane usually lays 4 to 6 slabs (2 to 3 slabs for each wheel track). Driving in wooden beams to form joint arrangements is accomplished immediately after the slabs are laid with a break of 20 to 25 m.

Laying slabs on thesurface occupies a team of 4 people: the crane driver, two riggers and a worker to close up the joints. The productivity of such a team is 100 to 130 m. of one-lane surface per shift.

For building track surfaces of reinforced concrete and timbered wooden slabs a specila slab-layer has been desinged and serially manufactured (type DUP-1 and DUP-2).

The slab-layer (fig. 196) is designed on the basis of dump truck MAZ-205, equipped with a generator and two crane-beams along which two power tackles move. The power tackles are meant to lift the slabs from a stack or the bed of a truck, to move them along the crane-beams and to lay them in the planned location. Each power tackle can lift, carry and lay a slab onto the right, or correspondingly, the left wheel track. The drive for each power tackle in a one-kilowatt electric motor.

Slab-layers have the following technical characteristics:

	Model Dup-1	Model Dup-2
Overall dimensions, m.:		
length ...	11,0	11,2
width ...	3,05	3,0
height ...	3,77	3,42
Cantilever flight, m.:		2,2
forward ...	2,0	3,4
rear ...	2,9	5
Lifting power, metric tons ...	5	8,0
Lifting speed m/min. ...	8,0	
Slab carrying speed along crane-beams m/min. ...	20,0	16,0

The slab-layer can transport 6 to 8 slabs per trip. For transporting them distances over 3 km. the slab-layer is outfitted with a specially equipped twin-axle trailer based on the serial logging detachable trailer. The slab-layer with trailer can carry 20 to 25 slabs per trip.

At the stockpile the slab-layer drives right up next ot a stack of slabs so that the forward cantilever is located over two piles. Using the power tackkes, two slabs (one from each pile) are lifted with special slaws, moved down the crane-beam and laid on thetrailer. The rigging is done by two workers. Operating the lifting, carrying and depositing mechanisms is carried out by the slab-layer driver.

The slab-layer drives to the laying site in forward gear. The slabs are lifted by the power tackles with claws, carried down the crane-beams and after being properly oriented by the workers, laid on a prepared foundation. In one stop 2 slabs can be laid (one slab for each wheel track), then the slab-layer moves ahead on the newly laid slabs and the operation is repaeated. After laying all the lsabs brought in a single trips the slab-layer turns around and goes after a new load.

If the slab-layer cannot turn around, the trailer is suspended from the crane-beams and the slab-layer moves in reverse to the nearest siding where it makes its turnaround and the trailer is installed in the transport position.

The productivity of the slab-layer for slab laying only is 140 to 170 m. of one-lane surface per shift.

Experience in dismantling track reinforced concrete surfaces has shown that great forces of adhesion arise in wintertime between the slab and the ground, exceeding the weight of the slab by 2 to 3 times.

In summertime lifting slabs laid on a sand foundation presents no difficulties. To reduce the effort of separation one side of the slab is lifted first, then the entire slab. Before lifting the slab is cleansed of dirt and the joint taken apart. A 4-worker brigade works on dismantling one-lane surfaces. The brigade's prodictivity is 115 to 120 slabs pershift.

The method of dismantling track surfaces with a slab-layer depends on soil conditions. If the ground will support a slab-layer with trailer the dismantling process is carried out on the following plan: the slab-layer turns around at the nearest siding and moves in reverse without its trailer to the end of the surface and drives off it so that the forward cantilever of the cross-beam is located over a pair of slabs. In one step the slab-layer takes up 2 slabs (one from each wheel track) and then moves to the next pair of slabs and so forth.

If the ground is weak the method described is not appleied. In this case the dismantling process consists of the following: at the nearest siding the slab-layer turns around without trailer, and moves in reverse to the site of dismantling the surface. The rear cantilever of the slab-layer's crane-beam is positioned over the last pair of slabs on the surface. The slab-layer loads on two slabs then moves ahead the length of one slab and the operation is repeated. Completely loaded, it returns to the siding and reloads the slabs on the trailer.

Time expenditure fordismantling one pair of slabs takes 5 to 6 min. It is most effective to use a slab-layer for laying and dismantling surfaces when transporting slabs over distances up to 3 km.

Rigid wooden surfaces are laid the same way as those of reinforced concrete, i.e. by mobile cranes or slab-layers. Flexible wooden surfaces are laid by vehicles equipped as shown in fig. 193.

Flexible wooden ribbon surfaces are laid according to the following technique. Previously prepared links of surface are transported to the temporary road worksite. There the slabs are laid out on a specially prepared area and assembled into a ribbon 36 m. long. The assembled ribbon is rolled up around the drum of the laying device and carried to the laying site in this form. By this time the axis of the surface is being laid out and secured on the roadbed. The ribbon of surface is laid down by the forward motion of the laying device. Then the sling lines of thelaid ribbon are unhooked and the laying machine goes on to the surface assemble area for the next ribbon. For the laying machine driver to be best oriented to the prepared subgrade it is recommended to lay the left wheel track first, then the right.

Laying and assembling the ribbons is executed by roadbuilding transporter-layer type DTU (fig. 197), a mechanism on a trailer working in conjunction with tractor type TDT-55 or TDT-60. The structure of the laying apparatus consists

of working and drive drums, support frame and running gear. The transporter-layer assures spreading and winding the ribbon at speeds of: for laying, 1.5 km. per hr. and for winding, 1.8 km. per hr. For short distances the laying apparatus is moved by tractor; for significant trips by truck. Drive for the drum is carried out by a wind on the trailer tractor. A variety of the transporter-layer has been designed for location directly on the trailer tractor. In this case the working drum is located on the tractor instead of a trailer panel. Curves with a radius over 100 m. are set up depending on the tolerances of the joint fastenings. For radii of less than 100 m. additional inserts are laid into the joints on the outer side of the ribbon. The gap between tracks is 0.9 m. At tractor crossing sites the surface is inte-rupted and a wooden timbered deck is set up.

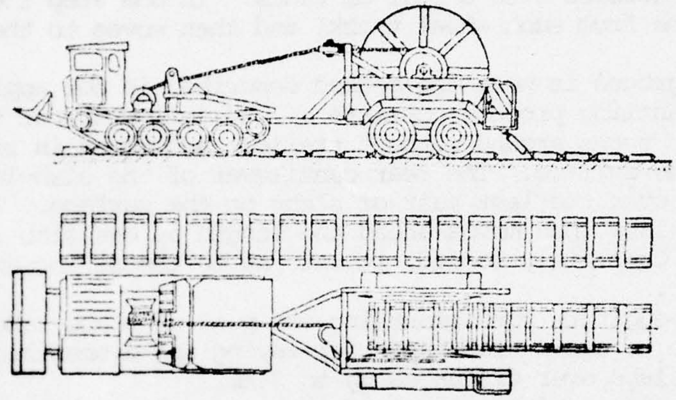


Fig. 197. Scheme for laying and assembly of wood-metal surfaces by a towed laying device.

For winding and unwinding the ribbon on the drum the bending angle between two adjacent alabs must be within a tolerance of 60°. Vehicle speed is permitted up to 20 jm/hr. The ribbon should be stretched after laying by braking the drum. An earthen strip 3.0 m. wide should be cleared parallel to the road under construction for driving the tractor with the laying apparatus. Construction and operation of prefabricated surfaces for temporary roads is implemented analogously to the above.

CHAPTER VIII

THE ECONOMICS OF CONSTRUCTING HIGHWAYS USING AGGREGATE SURFACES

36. BASIC PROPOSALS ON DETERMINING THE ECONOMIC EFFECTIVENESS OF PREFABRICATED PAVEMENTS.

Aggregate surfaces (foundations) may be viewed as a new advance in technology when compared with monolithic toppings and foundations and therefore the economic effectiveness of their use may best be determined by using a method for taking into account the effectiveness of adopting this new method.

As a standard, a more economical variation of the corresponding monolithic construction for highway surfaces will be used which satisfies the demands of the technological class of road. The characteristics of this standard will be compared with the properties of aggregate construction and by using this method the conditions necessary for providing a unified standard of durability and longevity for the compared monolithic and aggregate surfaces are more assured in the majority of cases. Deviations from this requirement are permitted during the organizational phase of construction, with varying amounts of materials consumed for the construction of temporary roads etc.

In each particular case a variation in the standard of durability and longevity of the road surface in comparison with the aggregate topping must be technologically and economically sound.

Substituting monolithic layers with aggregate, in addition to the differences in structure, inevitably leads to the necessity of using new types of technology and methods of organizing work and calls for other, almost fundamental changes in the various links of the construction process. Most of all the qualitative properties of the finished product change and frequently the materials used in their preparation as well.

A high quality of workmanship at the plants preparing the aggregate materials, and a high level of mechanization and automation make it possible in a number of cases to increase the quality of the product and lower the thickness of the aggregate surface or foundation, and consequently to lower the consumption of materials and volume of transporting time. A significant savings may be derived by using a more total and modern structure for aggregate surfaces, for example huge slabs of prestrengthened iron-reinforced concrete.

The use of prestrengthened materials for the production of monolithic iron-reinforced concrete surfaces is still linked to a number of technological and organizational difficulties. At the same time, at aggregate reinforced iron concrete plants fitted out

with modern equipment, the production of slabs of previously strengthened iron reinforced concrete has been completely mastered. The substitution of the usual monolithic cement surfaces with aggregate toppings of prestrengthened iron reinforced concrete makes it possible to reduce their thickness by approx. 25-35%.

In a number of cases an optimal solution to the construction of monolithic & aggregate road surfaces is linked with the use of various materials. For example monolithic cement surfaces may be replaced by aggregates of silicon-concrete or slag concrete slabs, gravel bases by aggregates from asphalt mineral slabs etc. The use of other materials for aggregate surfaces and bases is especially effective in the instance where they are available locally and nearby roads may be used. Thus in the preparation of asphalt mineral, slag concrete and silicon concrete slabs inexpensive local materials are usually used.

The use of new materials for aggregates not used in monolithic formations leads to changes in sources and methods of receiving them, changes in organizing the volume of transportation. All of the changes must be studied on a techno-economic basis for the use of aggregate formations for road surfaces.

The basic reserves of economy in the production of aggregates must therefore be in two interrelated directions, first in the improvement of forming slabs and the use of more inexpensive materials for their production, second in the improvement of technology and organization of construction on the basis of increasing the level of complex mechanization and automation with a transition to 24 hour production.

An indicator of the effectiveness of using different variants of aggregate surfaces and bases is derived by a number of characteristics. The most basic are: net cost of units of production; capital outlays connected with the use of new structural surfaces; the amount of time for capital outlays to show a return; the length of time for construction; the productivity of work.

The numerical significance of these indicators are determined for each variant of surface, method and organization of work.

In addition to the economic indicators it is also necessary to calculate other data characterized by the general working and living conditions of the laborers engaged in construction. Such indicators are: the improvement of working conditions (by transferring a significant part of the work from the job site to the plant shops) by an improvement in safety methods; an improvement in the living and cultural care of the workers (by transferring some of the workers from the job site to the factory); an improvement in the production and qualification of workers (by ending seasonal work and changing to year round production).

Although the enumerated indicators are frequently difficult to evaluate numerically it is still necessary to calculate them when selecting one variant or another.

In conjunction with the methods used at present for determining the economic effectiveness of introducing new types of production, a generalized indicator of estimated expenditures is used for comparing indicators of net cost and capital outlays for different variants of aggregate surfaces with the standard (a more economical variation of monolithic road surfaces):

$$R = C + E_H K, \qquad (174)$$

where R is the indicator of the estimated expenditures (in rubles) for 1 km or for 1 m^2 of road surface; C - the net cost of units of production (1 km or 1 m^2 of road surface); K - the capital outlay (the value of funds) for one yearly output of production-specific capital outlays (a specific fund capacity); E_H - norm coefficient of the effectiveness of construction (not less than 0.12).

The indicators of the estimated expenditures may be conclusively by selecting the variation with the maximum economic effectiveness.

The construction of aggregate road surfaces will be economic effective in those instances where the indicators of the estimated expenditures for its construction is less than the indicators of the estimated expenditures for the construction of the monolithic formations used as the standard.

With several variations of forming aggregate surfaces, the variant with a lower indicator of estimated expenditure will be used. Other indicators (the length of time for construction, the productivity of work etc.) serve as additional characteristics for the compared variants. In specific instances when there are general conditions limiting the length of time (for construction, the amount of resources consumed etc. additional indicators may show a conclusive effect on the selection of the variant. With a uniform durability and longevity of the standard and the aggregate formation, the sum of the computation according to formula (174) immediately determines the variant. However in specific instances the durability and longevity of the aggregate structure may be increased by using materials of higher quality and improved production methods (a better mixture settling etc.).

For comparing the estimated expenditures characteristic for the construction of road surfaces with different durability factors, a coefficient is introduced which adjusts for the new length of service of the structure by calculating the differences in expenditures μ. In this coefficient the magnitude of expenditures necessary for achieving the variations witb the lower length of service (44) is increased, i.e.:

$$\mu = 1 + \frac{\gamma - 1}{(1 + E_{HH})^{T_1}} \qquad \mu = 1 + \frac{\gamma - 1}{(1 + E_{нп})^{T_1}}, \qquad (175)$$

where E_{HU} is the normative coefficient of the effectiveness estimating the uniform expenditures ($E_{HU} = 0.08$)

$$\gamma = \frac{T_2}{T_1}$$

T_1 - the length of service of the structure used as the standard (in this case the monolithic road surface); T_2 is the length of service of the new structure.

Formula (175) for determining the coefficient of μ is justified if $1 < \gamma < 2$.

Sometimes substituting the formation of the road surface may lead to differences in outlays for its maintenance in the process of future use. If this difference (an increase or decrease) is significant, then an evaluation of the economic effectiveness of the different variants must compare not only the estimated construction expenses but also the expenses during the period of use. The expenses of future years is estimated to the current period to account for this, using the formula

$$K_{Hp} = \frac{K_T}{(1 + E_{HU})^T} \qquad K_{\text{нр}} = \frac{K_{\text{т}}}{(1 + E_{\text{нп}})^{\text{т}}}, \tag{176}$$

where K_{Hp} is the expenditures, estimated to the current period; K_T is the expenditures, estimated occurring through T year; T is the period of future expenditures in years.

In formula (174) the net cost of construction has more numerical significance in the majority of cases. This is determined by using specific calculations for each type of work. The use of estimated financial calculations and individual wage rates is not recommended. Average values for materials and average costs of machinery replacements are used, which do not take into consideration all of the peculiar features of productivity for each actual variation and the data determines only an approximate average cost of construction.

It is recommended that one also determine the numerical significance of other indicators not by coarse data but by the basis of individual detailed evaluations.

In order to determine the numerical significance of the economic indicators for aggregates it is necessary to take into consideration that the magnitude changes significantly in relation to the volume of construction. The net cost of a slab will be less with a peak load on the productive capacity of the plant engaged in construction. The net cost of the construction-assembly work for producing the aggregate will be less with a peak load on the work brigades engaged in the operation of laying and joining the slabs.

The general cost of constructing small sections of aggregate in terms of extension frequently increases due to an inefficient use of workers transport facilities and machines for small volumes

of work. Thus for small sections of work it is possible to determine only approximate experimental economic indicators. According to the degree of growth of the volume of construction the net cost of using aggregates is lowered due to a better use of working methods and material resources as well as a result of better assimilating new ways of work and increasing the productivity of work in the final analysis.

37. AN EVALUATION OF THE ECONOMIC EFFECTIVENESS OF USING AGGREGATE SURFACES.

Some of the basic construction elements in aggregate surfaces are slabs, joint layouts and seams. The structure and dimensions of the slabs are determined by the layout and dimensions of the slabs, number of joints and the length of the seams on the uniform area of the surface.

A selection of structural slabs is accomplished by a method on variant planning or the basis of a complex techno-economic analysis of the different variants. For an objective evaluation of the various structural decisions it is necessary that the techno-economic indicators are determined. Estimated loads effecting the aggregate surface must be identical as well as its longevity. In addition the qualitative indicators of construction, longevity and service must be identical.

In general the comparison depends on the following basic techno-economic indicators: 1) the cost of 1 m^2 of aggregate surfaces; 2) the expenditure of materials for 1 m^2 area of the surface; 3) Labor consumption per 1M^2 of pavement area.
4) the number and dimensions of the slabs; 5) the weight of one slab.

In addition to these numerical indicators the following must also be taken into consideration: the availability of materials; the methods of preparing and laying of each variant structural slab; the availability of corresponding equipment for preparing slabs and for laying them on the surface; the conditions for transporting the slabs from the factory to the place of installation; the methods of joining the adjacent slab; the peculiarities of the necessity for constructing a base under the aggregate surface using slabs of the same structure; the special features of future maintenance and repair of the aggregate surface.

In specific instances the necessity of taking additional indicators into consideration may arise. For example for aggregate surfaces of temporary roads the following data is important: the ability of transforming the construction site (the number of installations and dismantlings without repairs); the methods of assembling and disassembling the joint formations etc.

A final decision in selecting a variation of structural slab should be made only after a thorough study of all indicators.

At present a more detailed method of economic evaluation of planned decisions concerning aggregate iron reinforced concrete surfaces has been developed. The basic position of this method may be used also for studying the layout of slabs of other materials.

The main indicators in evaluating a structure are its estimated cost. Methods and norms for determining the estimated cost and work capacity of aggregate iron reinforced concrete structures at different phases of planning is used for determining this. (Series 2-27-III developed by Giprotis NIIZh Bom and other institutes.) This allows for the calculation of consumption at all levels of production beginning with the preparation of cement mixtures and ending with the formation of slabs for the road.

The full estimated cost for constructing a surface is determined by the following formula:

$$C_{\pi} = 1.196 \left[1.02(C_K + C_T) + C_M\right] K_X, \qquad (177)$$

where 1.196 is the coefficient of the consumed material and projected consumption for the structure; 1.02 is the coefficient which calculates the materials consumed in preparation and warehousing; C_K is the estimated cost of preparing one unit of iron reinforced concrete; C_T is the cost of transporting the structure to the job site; C_M is the cost of production; K_X is the coefficient which calculates the winter price rises.

In turn the estimated cost of producing an aggregate surface (in rubles) is determined by the formula:

$$C_K = 1.03\ (C_{\delta} + C_{CT} + C_{H \cdot A} + C_{HAN} + C_{\pi\ II} + C_{\%}), \qquad (178)$$

where C_{δ} is the cost of the concrete mixture by prepaid distribution mixers used for concrete laying and located at the plant; C_{CT} - the cost of steel of all types for producing hardware and insertion pieces using prepaid warehouse metals from the plant; C_H - the cost of preparing non-stressed hardware; C_{HAN} the cost of preparing stressed hardware; $C_{\pi\ II}$ the cost of preparing inserted steel pieces; $C_{\%}$ the sum of the consumed materials in casting and thermal treatment; 1.03 - the coefficient for calculating the projected totals.

The cost of the cement mixture is determined by the formula

$$C_{\delta} = \text{б}_K \Gamma \qquad (179)$$

where б_K is the volume of the concrete mixture in a closed body, m^3 (derived from a working plan of the piece of equipment); K_{δ} the coefficient of consumption of the concrete mixture in rubles (depending on the type of cement and fullness of the load).

On the basis of the occurrences resulting during experimental production techno-economic estimates were derived, characteristic in the production of large scale previously strengthened iron reinforced concrete slabs in assembly lines at these plants. The indicators shown in tables 54, 55 and 56 were determined under the

TABLE 54

	Types of Technology		
	conveyor	vibration roller	continuous assembly production
Yearly productivity of one one line thousands M^2	330	500	150
Specific capital outlays related to the organization of production at active plants rubles/m^3	6.7	4.5	4.15
Work capacity of producing 1 m^2 slabs men/hours	0.73	0.41	0,95
Net cost of 1 m^2 slab, rubles	4.52	3.94	4.84

TABLE 55

Practical Technology	Fund capacity rubles	No. of workers for 1000 m^3 of ready-made product	Fund efficiency, rubles	Productivity of work for one worker m^3
Total for Industry	1.18	9.79	0.98	134.3
Among them:				
Continuous assembly production	1.19	9.6	0.99	135.2
Stand	1.25	14.8	0.91	109.0
Conveyor	1.15	5.9	0.96	206.9
Roller stations .	2.30	11.2	0.44	77.8

TABLE 56

Type & Form of Slab	Consumption of materials for $1m^3$				General cost of materials rubles	Productivity men/hours	Net cost rubles for m^3	Estimated tempering value for m^3
	Concrete		Hardware					
	kg	rubles	kg	rubles				
Square with beveled edges, dim. 2 x 2 x 0.16	1	16.50	28	1.74	18.24	5.56	32.98	34.60
Rectangle with dim. 3.5 x 2 x 0.20	1	16.50	27	1.68	18.28	5.20	31.04	32.60
Hexagon a = 1.2, h.= 0.16	1	16.50	21	1.51	17.81	5.47	32.49	34.20
Caisson rectangles with the dimensions 3.5 x 2.5 x 0.16	0.69	11.40	55	5.10	16.50	4.29	30.80	31.90
Road vibration rollers ΠBII-5-30	0.72	11.90	56	5.20	17.10	4.45	30.93	32.50
Rectangle ΠIIR-2-60	1	16.50	71	6.60	23.10	6.10	38.15	40.30
Hexagon a = 1.16, h = 0.18	1	16.50	43	4.04	20.54	5.51	35.22	37.00

conditions at the Moscow plants.

From the comparison of the costs of slabs of previously strengthened material and from regular cement it is apparent that the formation of previously strengthened slabs makes it possible to improve the construction of slabs and lower the consumption of materials.

More durable and more initially expensive materials are used for slabs of previously strengthened iron reinforced concrete. However, the price increases of materials used in previously strengthened surfaces does not approach the increase in durability. Thus, for example, steel used in previously strengthened iron reinforced concrete formations is 5 times more durable than steel used in normal iron reinforced concrete, but the cost is only twice as much. An analogous situation occurs with concrete when the durability is doubled the cost increases on by 10-15%. Therefore the use of previously strengthened materials in iron reinforced slabs of aggregate surfaces allows one to not only economize in materials but also to lower the cost of units of surface area.

In Table 57 the basic techno-economic indicators of constructing and using severals types of aggregate surfaces of concrete and iron reinforced concrete slabs are given with an area from 4 to 12 m^2.

TABLE 57

SEE PAGE 351(b)

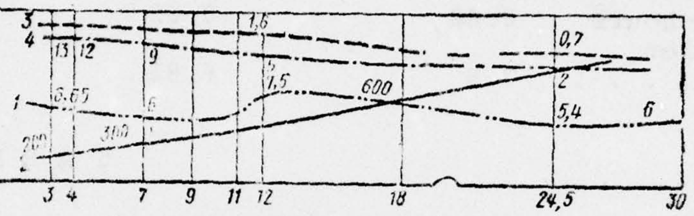
These formations, together with their positive indicators, are also characterized by an increase (in comparison with monolithic surfaces) in work capacity of construction and by a significant

TABLE 57

Characteristics of slab	Cost of slab rubles 1 m^3	Cost of slab rubles 1 m^2	Weight of 1 m^2 T	The cost of transporting a 1 m^2 slab 15 km, rubles	The cost of production for 1 m^2, rubles	The general cost of construction for 1 m^2, rubles	The work capacity of construction for 1 m^2, men-hours	Specific length of joint seams for 1 m^2, m	Yearly consumption of resources for 1 m^2 in rubles
Square with beveled edges: 2 x 2 x 0.16 m . .	37.6	6.17	0.41	0.43	0.18	6.78	1.6	0.58	0.12
Rectangular slabs: 3.5 x 2 x 0.2 m	34.6	6.93	0.5	0.53	0.22	7.68	2.31	0.64	0.09
Hexagon slabs: side 1.2 m . . . thickness 0.16 m	34.2	5.32	0.38	0.40	0.19	5.91	1.63	0.96	0.13
Caisson rectangles: 3.5 x 2.5 x 0.16 m	31.9	5.1	0.28	0.30	0.18	5.58	1.43	0.56	0.58
IIB - S - 30: 3.5 x 3.2 x 0.18 m	32.5	5.86	0.32	0.34	0.19	6.39	1.58	0.45	0.07
II - 3 - 2c 6 x 2 x 0.14 m	40.3	5.64	0.34	0.36	0.16	6.16	1.67	0.54	0.08

year round use of resources. The high work capacity is a result of using imperfect laying devices with low productivity, and also of large amounts of manual labor on the sealing of joints & seams. A significant consumption of materials is due basically to the large individual lengths of the seams as a result of using slabs with small dimensions.

A study conducted by Master of economic sciences L. K. Zaitsev has shown that the most important techno-economic indicators (specifically cost of construction, used materials, work capacity of production) depend on the dimensions of slabs that are laid. The larger the slab the higher the productivity and the lower the specific consumption of materials for the construction and use of aggregate surfaces. (Diagram 198)



The area of the slab M

Diagram 198. The relationship of the productivity, work capacity, cost of preparation and use of materials to the dimensions and form of the slab:

1 - cost of preparation of 1 m^3 slab in rubles; 2 - the productivity in replacing M^3; 3 - the work capacity of constructing 1 m^2, men-hours; 4 - used materials for 1 m^2 in a year

The best indicators show slabs with huge dimensions (an area larger than 10 m) and simple straight contours of previously strengthened iron-reinforced concrete.

An increase in the dimensions of the slab in the plan makes it possible to also significantly lower the extension of the joint, so that in combination with the efficient construction of such joints the necessary smoothness of the surface is guaranteed, the stability of the slab under traffic conditions is increased and the consumption of materials for the composition and future repairs of the road is lowered. At present the technical possibilities of modern technology and equipment, and the load capacity of transport and hoisting vehicles make it possible to lay slabs with a width of 3.5-3.75 m and a length of up to 10 m, and in special cases up to 15 m. A comparison of the techno-economic of monolithic surfaces with aggregate surfaces of large slabs is given in Table 58.

The relationship of the length of the joint to the dimensions of the slab of several types of iron reinforced concrete slabs is characterized by the data given in Table 59. The larger the dimension of the slab, than smaller the length of the joint necessary for a single slab area.

TABLE 58

Indicators for 1 m^2 of surface	Mono-lithic cement surface	Aggregate surfaces of large-dimension previously strengthened aggregate slabs	% in Relation to concrete surfaces
Thickness of surface, cm	22	12	55
Cost of steel & concrete, rubles	4.66	3.16	68
Weight of structure, T .	0.54	0.30	54
Work capacity men-hours	0.68	0.62	91
Cost of construction, rubles	7.6	6.83	90

TABLE 59

Type of indicator	Previously strength-ened PDG-2-6c	Iron reinforced concrete on longitu-dinal foun-dation beam (KAD)	Hexagon DS-Sh-2 "Mosinzh-proekt"	Previously strength-ened structures V21S1
Dimension of planned slab	2.0 x 6.0	1.75 x 3.0		3.5 x 6.0
Area of one slab m^2	12	5.25	3.5(1.75)	21.0
Number of slabs for 1000 m^2 of aggregate surface . . .	84	190	213+144	48
Number of transverse joints for 1000 m^2 of aggregate surface 144 m	24	48	71	24
Length of joints for 1000 m^2 of aggregate surface - m:				
a) transverse . .	168	336	325	168
b) longitudinal .	432	432	650	144
c) general	600	768	975	312
Specific length of joint for 1 m^2 of aggregate surface:				
in m	0.60	0.77	0.98	0.31
in relative cases	1.9	2.5	3.2	1.0

TABLE 58

TABLE 59

The maintenance qualities of aggregate surfaces for highways depends not only on the specific length of the joint but also on perfection of its construction. The more perfect the construction of the joint, the better the evenness of the surface and the lower the impact during the passage of vehicles from one slab to the next. No less important is the preservation of the positive qualities of the joint for the right length time. The longevity of the joint must be equal to the slab. At the present time the previously-strengthened joint is considered to be more perfect. The joints of large previously strengthened iron reinforced concrete slabs may be expediently arranged to guarantee a unified quality of

workmanship of the entire aggregate surface under heavy loads.

A selection of the methods of forming previously strengthened joints of varying formations, used with slabs with dimensions of 3.5 x 6.0 m and a thickness of 14 cm is given in Table 60, from which it can be seen that the strengthened joint unions used with lifting jacks as flatly turned pipes are approximately 1.5 times more expensive than others types of construction. This can be explained by the high cost of steel in these pipes. The use of highly durable pipes made of polymeric materials significantly lowers the cost of constructing such joints and makes it possible to simplify the methods of finishing. An increase in the quality of the joint (its durability, smoothness, longevity) completely justifies an increase in consumption of materials for its construction, even with the use of flatly turned steel pipes.

Previously strengthened joints with threaded couplings possess the best indicators of work capacity, cost of using equipment and general cost of construction although the cost of producing the elements for joining is slightly higher in comparison with other types of joints.

The cost of producing the elements of threaded couplings, given in Table 60, determines the results of preparing them on lathes and milling benches. A significantly lowered cost may be achieved in preparing the elements of the threaded couplings by using die cutting, precision casting or casting under pressure.

The methods of production help to not only lower the working time, but also make it possible to significantly lower the cost of such expensive materials such as metal. The possibility has not been ruled out that highly durable materials produced in plastic masses may be found for use in threaded couplings. Such couplings, together with their simpler and lower cost of production, may have less weight and possess a long time of service.

By filling the seams between the slabs with cement mortar, the cost of using threaded couplings for 1 m^2 of aggregate surface, comprises 0.131 rubles. By filling with a glue mastic it is approximately 0.20 rubles. The use of a glue at the same time increases the durability characteristics of the joints and, consequently, the maintenance qualities of the aggregate surface as a whole. Thus a small increase in expenditures for the above structure is warranted in the short run.

The cost of constructing joints at the "Mosinzhproekt" for 1 m^2 of aggregate surface equaled 0.196 rubles, i.e. approximating the cost of the joint with threaded couplings and with seams filled with glue mastic. However the joint possessed a deficiency, since in the process of preparing it it was necessary to simultaneously

TABLE 60

Type of indicator for 1000 m^2 of aggregate surface	Formation of joint couplings					"Mosinzhproekt" Institute
	welded			threaded		
				with stand type sleeves		
	for slabs with wire hardware with cut pipes	for slabs with core hardware with cut pipes	for slabs with core hardware without cutting the pipe	seams filled with mortar	seams filled with glue mastic	
Cost of producing elements for joint coupling in rubles	16.77	11.67	11.67	66.24	66.24	3.00
Cost of materials for coupling, rubles	245.5	207.2	252.3	55.20	123.5	79.0
Consumption of steel for coupling, kg.	2570	1850	1850	470	470	70.0
Cost of using equipment, rubles . . .	15.3	12.7	7.80	4.2	4.2	57.0
Work capacity, men-hrs.	54	52	33	12	12	116.0
Cost of constructing joints, rubles . .	324	257	288	131	200	196

TABLE 60

use a large number of flat jacks (2 jacks per joint), and in addition the volume of work increased in order to equalize the gaps between the slabs to 14 cm. An essential deficiency of such joint couplings includes the difficulty in joining the concrete evenly along the entire length of the joint.

By increasing the dimensions of the slab the volume of work necessary to fill the seams and join the slabs is lowered significantly. In Table 60 the volume of work is determined aggregate surfaces with slabs having dimensions of 3.5 x 6.0 m. At the present time there are examples of aggregate surfaces with slabs of significantly large dimensions.

38. AN EVALUATION OF THE ECONOMIC EFFECTIVENESS OF ORGANIZING THE CONSTRUCTION OF AGGREGATE SURFACES

The economic effectiveness of aggregate road surfaces in comparison with monolithic surfaces is especially apparent in the sphere of organizing construction, since the greatest effect on the economy of construction in the majority of cases turns out to be the method of producing the slabs and transporting them, as well as changing from seasonal to year-round production.

As a standard for comparing and evaluating the economic effectiveness of the various methods of organizing the production of aggregate surfaces, the optimum methods of production for identically durable monolithic surfaces are used under the actual given conditions.

Shown below is a method of economic evaluation for the organization of manufacturing slabs and transporting them to sites building prefabricated concrete and reinforced concrete surfaces (or prefab asphalt-mineral foundations) on the example of several most characteristic varieties. Technical characteristics (by terms of service and transportation - operational indeces) of comparable prefab and monolithic surfaces are taken to be equivalent.

One of the most frequently encountered variants is the organization of slab manufacture at a stationary factory with a service lifetime many years long, serving the requirements of various building projects in a zone with a large (several tens or hundreds of k.m.) radius of activity. Such plants are generally well outfitted with modern technological equipment and additional capital expenditures for organizing an output of slabs are not significant. At the same time the factory's location relative to the road under construction, as a rule, does not meet requirements for minimum transportation expenses. Frequently the distance from the factory to the road under construction exceeds the maximum (according to technological considerations) distance for trucking concrete mix. Under such circumstances using an existing stationary factory for producing monolithic concrete surface is unfeasible.

In the event that monolithic pavement use is implemented it is necessary to build a special factory to manufacture cement concrete mixtures, locating it so as to reduce the transportation of these mixes to the minimum demanded by technological conditions. Transporting ready slabs over long distances does not meet with technological difficulties.

Using slabs manufactured at a stationary factory for building a prefab pavement is a paying proposition under conditions where the given expenses for slab manufacture, laying and transportation are less than the given expenses for producing monolithic paving from mixes manufactured factories built with the most advantageous location specially for the construction of a certain road.

The mathematical expression of the given condition (for one k.m. of pavement) is

$$N(C_m + C_T + C_I) + E_s \frac{K}{P} \leq Q(C'_m + C'_t + C_L') + E'_s \frac{K'}{P'}, \quad (180)$$

where N is the number of slabs laid on one k.m. lf road; C_m, C_T, C_I are respectively the costs of manufacture, transportation and installation of one slab; K is the capital expenditures for setting up a stationary factory for putting out slabs of the given structure, means of transportation and slab installation equipment; P is the annual productivity of the stationary factory in slab output, expressed in kilometers of prefav pavement; P' is the annual factory productivity of ready mixes

in k.m. of pavement; Q is the volume of concrete mix needed for one k.m. of surface of uniform strength with the prefab type in cubic meters; C'_m, C'_T, C'_L are the cost of manufacturing one cubic meter of mix at a ready-mix concrete plant built to service a certain road, the cost of transporting the mix and the cost of laying it into a monolithic surface; K' refers to all capital expenditures for building the ready mixes plant, means of transportation and equipment for laying the mixes; E_s is the standard-rate coefficient of building efficiency (not less than 0.12); E'_s is the coefficient of efficiency for construction of the ready mixes factory;

$$E'_s = \frac{1}{T_f}$$

where T_f is the working lifetime of the factory.

If T_f 8 years, then E'_s is equal to E_s, that is, equal to or greater than 0.12. But factories built especially to service one road are frequently in operation for shorter terms, for example 2 or 3 years. In these cases E'_s will be correspondingly equal to one half or one third.

When T_f 8 years expenditures for the ready mixes plant (to be included in the sum total of capital expenditures K) should be specified minus the return sum receivable under the plan at the time of relocating the plant for new projects. The size of the return sums should be reduced to the year of constructing the factory by dividing by $(1 + E_{sr})^T$, where $T = T_f$, and E_{sr} (standard-rate coefficient of efficiency for the reduction of expenditures over time) is equal to 0.08.

Definition of the necessary cost data for equation (180) is produced by a calculation which takes into account all the particulars of the actual and specific unit under construction.

If the road has a significant extent then it is necessary to build several factories to supply it with mixes. In this case the cost of factory construction and the cost of manufacture, transportation and laying the mix withing the boundaries of the zone it supplies are figured separately.

Another possible variation would be the manufacture of slabs at a temporary work yard located in direct proximity to the road being built, roughly in the center of the section it services. By comparison with previously described methods this variety is distinguished by the following features: The distance for hauling slabs from the workyard to laying sites is mimina. and transportation expenses are correspondingly signivicantly less; The slab manufacturing cost is higher since manufacturing conditions at a temporary yard are worse than at a stationary factory; capital expenditures for equipment at a temporary workyard are usually not great, but are greater all the same than preparing a permanently active stationary factory for slab output.

To evaluate the economic efficiency of the second variety

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JAN 77 V M MOGILEVICH, E N DUBROVIN

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it is also necessary, as in the previous case, to compare the given cost of one k.m. of prefab surface R_{pref} with the standard which is the given cost of one k.m. of monolithic surface R_{mon}. Construction with prefab surfaces will be economically expedient when $R_{pref} \leq R_{mon}$.

To insure building of monolithic surfaces with cement mix the construction of special cement concrete plants is required, usually of the temporary type. If the building organization forceses production wprk making slabs only during summer conditions and the quantity of temporary workyards for slab manufacture is equal to the quantity of factories producing mix for making monolithic surface, then in the majority of cases the cost of prefab surfaces turns out higher. This is explained by the fact that the volume of work turned out at a slab manufacturing plant is greater than the volume of work on the output of a corresponding quantity of mix. Slab manufacture necessitates the output of roughly the same quantity of mix plus carrying out the additional tasks of forming and condensing it and moving it about the workyard. Consumption of labor and energy in these additional operations usually exceed the savings obtained in reducing the tasks carried out directly on the road.

However, in several cases, owing to design ratios in the slab structure, an increase in work quality, adoption of prestressing and other measures it is possible to significantly reduce the thickness of a prefab surface (compared with the thickness of a monolithic type) and correspondingly reduce the quantity of mix required. Besides this, the economic savings on prefab surfaces in the given variety of work organization can be substantially increased if the hauling distance for slabs is not limited by technological requirements. With a reduction in the number of workyards (compared to the number of ready-mix concrete factories) owing to an increase in the zone they supply, it is possible to create a situation wherein the reduction of expenses for organizing workyards compensates other increased expenses (including transportation) for the construction of prefab surfaces.

On several projects the building organizations foresee the possibility of using the same plants, located near roads under construction, for manufacturing ready mixes in summer and prefab surface slabs in winter. This makes possible extending the factories's supply zone woning to the issue of different products to different sectors.

In each zone sections located near the factory are singled out to have monolithic pavements built on them during the summer period. The borders of these sections are defined by the technological limiting conditions of hauling distance. In the winter period they build prefab surfaces in the most distant sections or truck slabs into these sections manufactured during the winter for their subsequent use in the summer. The scheme for the similar distribution of monolithic and prefab surface sections (or foundation sections) and plants to provide the necessary half-finished products and manufactured articles is shown in fig. 199.

To compare the above expenditures necessary for constructing prefab and monolithic surfaces in sections l_3 and l_4 we specify the economic efficiency of prefab structures by the given variety of organization for manufacturing and transporting slabs. In specifying the sum of given expenditures the following are taken into account. To build a monolithic surface on sections l_3 and l_4 it is necessary to erect two additional ready-mix concrete plants (CCF no. 3 and no. 4) (CCF = concrete cement factory -transl.) The necessity for additional plants for building prefab surfaces in these sections no longer arises but the volume of transport work increases significantly in connection with delivering ready slabs to these sections from distantly located plants no. 1 and no. 2. At the same time, thanks to the changeover of plants no. 1 and no. 2 from seasonal to year-round production the unit production cost (for one m^3 of ready mix and one m^2 of ready slab) will be lowered. The degree to which it is lowered depends on the equipment adopted and climatological conditions of the building region. Under favorable conditions use of ready-mix concrete plants for winter manufacture of prefab surface slabs can lead to some reduction in the cost-price of constructing monolithic surface on sections l_1 and l_2.

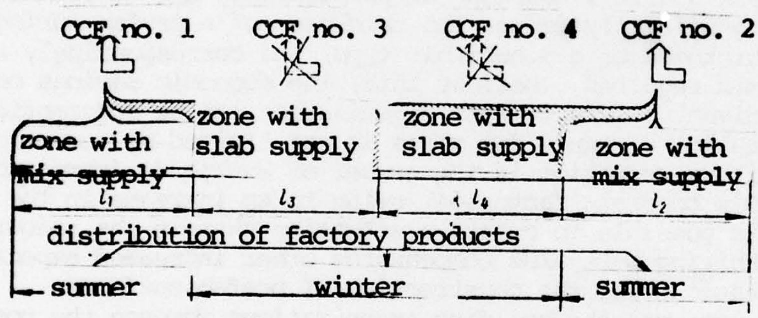


FIG. 199. SUPPLY SCHEME FOR VARIOUS CONSTRUCTION SECTIONS WITH MONOLITHIC AND PREFAB SURFACES.

The example just examined for organizing the manufacture and transportation of slabs encompass all pissible organizational schemes for preparation and transportation jobs for building prefab surfaces. Other varieties are also possible (sic), first and foremost those based on the skillful use of various local conditions in the regions of construction. The greatest economies from the application of prefab surfaces are normally achieved during the winter period. No transition from seasonal to year-round production of pavement construction leads to shortened construction schedules, which in the majority

of cases entails significant economic advantages both for the building organization and the national management. But at the same time the production of road building jobs under unfavorable winter conditions is connected with a growth in the complexity of the technology and an increase in their cost price.

The size of additional expenditures called for by work production in winter conditions depends on climate conditions in the building region, and also on the form and technology of the work in progress. In regions with a prolonged and frosty winter labor conditions for the workers and operating conditions for machinery and transportation worsen sharply, while freezing through the soil and crumbly materials freezing into a solid mass increases. Correspondingly, additional expenses rise for measures insuring the psssibility of work production in such unfavorable conditions. In regions with a short, warm winter additional expenses called for by road building work production in winter conditions are significantly less. Temperatures limitations fo work production also have substantial significance for pavement construction. Work on the construction of improved surfaces of the capital type (cement concrete and asphalt concrete) is halted during temperatures in the -10 degrees to -15 degrees C range. In periods with temperatures below 0 degrees (and for many materials below +5 degrees to +10 degrees C) work must be carried out by special technology requiring significant additional expenditures. Nevertheless, the greater part of installation work on arranging prefab surfaces can be produced at whatever negative temperature. The advantages of the transition from seasonal to year-round roadbuilding work production are especially appreciable in regions with a long winter. Construction conditions for monolithic and prefab surfaces at various times of year in one of the regions of Siberia are examined below by way of example. A short characterization of the region's climate is given on an abbreviated climatic chart (fig. 200).

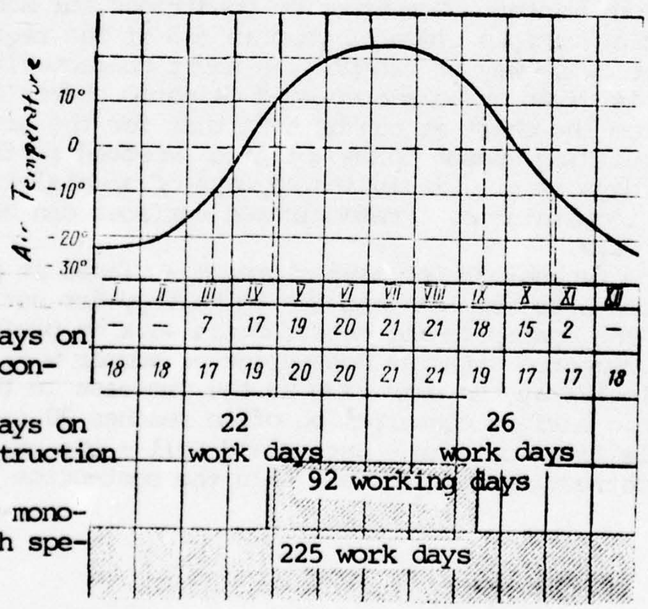
From the chart it can be seen that for the given conditions the length of the building season for monolithic improved surfaces comprises only 140 working days in all, including 48 days of special technology accounting for low air temperatures. Prefabricated surfaces can be build all year - 225 working days.

The technology for laying prefab surfaces in negative temperatures becomes much less ocmplex than the technology for setting up monolithic surfaces. The cost-price of construction work on prefab surfaces in winter conditions compared with the cost-price of summer work usually rises no more than 8 to 12% at the same time as the increase in the winter cost-price for monolithic surface construction often reaches 20 to 25% and more. At unfavorable times of year - Spring and Fall - the cost-price of pregab surface construction is also less than the cost-price of monolithic types.

For the conditions in Siberia, organizing the construction of monolithic surfaces during temperatures slightly below 0 degrees C extends the building season, but in no way finally decides the question of the building organization's year-round workload.

Construction with prefab surfaces guarantees the uniform use of worker cadres, building machinery and transportation in the course of an entire year. Moreover, a great economic effect for the national management is achieved by building prefab surfaces throughout the entire year, thanks to the significant speed-up in putting roads into operation. The prolongation of the annual building season for prefab surfaces in the given example is 85 work days (225-140) or roughly by 4 months more than the duration of the building season for monolithic surfaces. Assuming that production-live speeds for building monolithic and prefab surfaces are roughly equal then in the final sum the overall construction schedules can be shortened by 4 months.

In conditions similar to those considered in the example several varieties of construction organization may be upt in practice. For example, building only monolithic surfaces, using the workers during the winter on other projects and other types of work. In this case as a rule their level of usefulness, first of all by labor productivity goes down. It is possible to build with a variant type of prefab surface on the entire road. But in the majority of cases for similar conditions it is most expedient in the summer period (92 work days) to build monolithic surfaces; Spring, Fall and Winter (133 work days) to build prefab surfaces. The final decision should be according to the results of detailed colculations taking all other factors (not mentioned here) into account.



months

Number of working days on monolithic surface construction.

Number of working days on prefab surface construction

Period for building monolithic surfaces with special technology.

Period for building monolithic surfaces with ordinary technology.

Period for building prefab surfaces.

FIG. 200. ABBREVIATED CLIMATIC CHART FOR AN AUTOMOBILE ROAD BUILDING REGION.

The calculation of the economic effectiveness of the premature completion of road construction is carried out according to a method worked out by Coyuzdornii (doctoral science candidate M.N. Ritov). When working out the plans for the organization of the year-round construction with effective use of the winter period, they calculated the value of the economy obtained from shortening the construction time, and compared it with the value of additional expenditure which will take place with the carrying out of work under winter conditions. For convenience of comparing the value of economy and rise in price with different work organizations, the calculation results were determined in percentages to the cost of construction and installation work. The calculations were carried out separately for two variations of organizing the construction in winter conditions: the construction of monolithic pavements and the construction of prefabricated pavements. Then the economic effectiveness of both variations were compared with each other.

The calculated formulas for determining the economy were based on the fact that all the expenditures in constructing a highway can be broken down into two groups: the expenditures depending on the volume of work done, and the expenditures depending on the calendar time of the construction.

Since when shortening the construction periods, the volume of work in constructing the highway is unchanged, then the expenditures of the first group remain unchanged. The expenditures of thessecond group are reduced directly proportional to the shortening of the construction times.

The economies in the mechanized work are based on the the construction of the road cover; they may be obtained mainly due to better use of the present set of constructional and transport machines. With a shortening of the construction time, part of the expenditures are reduced, depending on the calendar time when the vehicles remain on the object (amortization deductions, payment for capital). The increase in the number of working shifts necessary for one average-scheduled vehicle due to the carrying out of work in winter, and also the increase of the yearly volume of completed annual work, leads to a reduction in the cost of the machine-shift, and consequently to a reduction in the unit of work.

The calculation of the anticipated economy in mechanized work due to the reduction of expenditures depending on the calendar construction period, can be carried out with the approximate formula:

$$P_1 = Aat \qquad (181)$$

where P_1 is the percent of reduction in constructional cost as a result of improving the use of mechanization means; A is the cost of using the vehicles in percentages of the general estimated cost of the construction, according to the recommendations of the Soyuz DorNII must be assumed to be A = 13-15%; a is the part of the constant expendituresiin machine-shiftcost, expressed in fractions of a unit; by way of orientation a = 0.4; t-is the shortening of the construction time, expressed in fractions of a unit of the general standard period os time.

The shortening of the construction times also guarantees obtaining economy due a reduction of the applied expenditures, which, like the expenditures for vehicle use, can be broken down into two parts: a)depending on the volume of performed constructional-installation work; b) depending on only the calendar building period.

The second part of the applied expenditures, called conditional-constant, were consumed basically on managing the construction and administrational-economic needs and is reduced proportionally to the reduction of the construction period.

The lowering of the cost of construction due to economy of the conditional-constant part of the applied expenditures in percentages of the cost of the entire project P_2 may be determined according to the formula

$$P_2 = Bb_2t \qquad (182)$$

where B is the standard sum of the applied expenditures in percentages of the general cost of the construction; b_2 is the conditional-constant part in the general sum of applied expenditures, expressed in fractions of a unit; t is the reduction in the construction time, expressed in fractions of a unit of the general standard period of time.

The values B and b_2 change in small limits for different ministries and departments. The SoyuzdorNII recommends calculating B = 14.5% (of the volume of constructional-installation work) and b_2 = 0.6. Substituting these values into formula (182) we obtain

$$P_2 = 8.7\ t \qquad (183)$$

One of the basic positive sides of the refusal of seasonal organization and a transition to year-round construction with equal load of the working crews is creation of a stable constructional collective and liquidation of the fluctuations in the number of workers.

The flow of the crews and the unequal demand for them in seasonal work causes additional expenditures assembling the workers, their preparation, in constructing living quarters and community services. Production suffers considerable losses from the insufficient qualifications of the workers unavoidable with their turnover.

With the creation of a stable collective of construction workers, there is an increase in the productivity of their labor and the average yearly number of them is reduced. Correspondingly, there is a reduction of the expenditures for living accommodations and cultural services of workers and their families. However, in the general case, it is very difficult to calculate the economy obtained from doing away with the turnover of working crews, Thus we are limited to an approximate calculation of the reduction of applied expenditures with a reduction of workers, according to the following formula:

$$P_3 = Ba_1a_1 \qquad (184)$$

where P_3 is the economy from maintaining a constant working crew in percentages of the cost of the entire construction; B is the standard sum of the applied expenditures in percentages of the general estimated construction; b_1 is the coefficient showing what part of the applied expenditures depends on the number of workers; $a_1$is the reduction in the number of workers in fractions of a unit.

For approximate calculations it is recommended to take B = 14.5% and b_1 = 0.297. Moreover, formula (184) takes the form:

$$P_3 = 4.3a_1 \qquad (185)$$

To determine the value of a_1 is possibleoonly by way of orientation. Usually, accounting constructional data are used realized in analogous situations, and they are compared with the average yearly number of workers based on 1 million rubles cost of completed constructional-installation work on objects with seasonal or year round carrying out of work.

On the basis of an analysis of the works of Glavdorstroya, CoyuzDorNII recommends taking a_1 = 0.09 for the preliminary calculations.

Oniindividual objects, the fluctuation in the number of workers reaches rather great values. The presence of even short-term "peaks" in the number of workers is connected with an increase in the expenditures of servicing them and above all providing them with living and communal services. These expenditures are especially feld when constructing roads in sparsely-populated regions.

The economic indicators P_1, P_2 and P_3 do not embrace all the possible reductions in the expenditures on the construction of highways with a transition from seasonal to year round production of work. On each concrete object, it is possible to obtain additional profit from skillful use of all the partial special features of winter construction. For example, from transporting the slabs in shorter directions with the use of ice passages and winter time hauling paths, laid down along virgin soil, from the construction of ice gauge roads with a mobile makeup in the form of high load sled trains hauled by tractors, etc.

The final economy results from the construction of prefabricated pavements in winter time obtained by road construction organizations which is evaluated by the coefficient of economic effectiveness E_s

expressed in percentages of the general estimated cost of constructional-installation work. It is determined as the algebraic sum of the economy obtained from improving the organization of construction with a transition to equal year-round carrying out of work and the additional expenditure caused by the winter conditions

$$Э_s = P_1 + P_2 + P_3 - \mu, \tag{186}$$

where E_s is the coefficient of economic effectiveness of carrying out the road construction work in winter time; P_1, P_2, P_3 is the reduction in the cost of construction in percentages of the estimated cost of constructional-installation work determined according to formula (181), Eq. (183) and (185); μ is the winter increase in cost, also in percentages of the estimated cost of constructional-installation work, determined with a calculation in accordance with the planned carrying out of the work.

Taking into account the positive sides of carrying out the construutional work in winter, the existing norms permit some limited determination of their increase in cost. A document determining these limits if the "Temporary Norms of Additional Expenses in carrying out constructional-installation work in winter" (VNDZ-69) confirmed by the Gosstroem SSSR for use from 1 January 1969. [45]. In the norms, account is taken of the influence of climatic conditions and the special features of carrying out different forms of work.

The entire territory of the USSR is divided into ten temperature zones. The first zone includes the warmer southern regions, the tenth one includes the colder northern regions. The additional costs permitted by the standard with construction in winter conditions of different types of road coverings, expressed in percentages of the cost of constructional-installation work, change from 0.9% for the Ist zone to 10.9% for the tenth one. In each particular case, the acceptable increase in cost must be determined using the corresponding breakdown of VDNZ-69.

If the value of the coefficient of economic effectiveness of carrying out road-construction work in winter E_s are equal to the positive number or to a negative number, but less then the absolute value of the permitted standard increase in cost, then the organization of construction in the winter period must be considered expedient when worked out to a sufficient degree. If the negative value of E_s is larger than the acceptable norm for additional expenditures, then it is necessary to re-examine the organization of winter work, changing the forms of the work and reducing their volume.

So, in individual cases, in the construction of prefabricated pavements in winter it is possible to dispense with installation of the slabs, since doing this type of work is usually connected with large volumes of additional expenditures. Moreover, winter work is limited to preparing the transporting the slabs. The accumulation of the reserve of slabs on the road makes it possible to install the slabs faster with the onset of warmer weather. However, in this case, reducing the constructional periods evidently will be

less than equally carrying out the installation of the pavement in the course of the entire winter.

Another variation for reducing the additional expenditure is the reducing of the volume of laying the slabs by the organization in winter time with reduced speed or discontinuing the laying in the less favorable cold months (for example in January and February).

The economic effect obtained directly in the sphere of construction reflects only some positive sides of prematurely bringing the road into use. Reducing the construction times and prematurely bringing the road into use creates an increase of national income for the state: thanks to the reduction in the cost of transportation, obtained with the premature transfer of traffic onto a road of a higher technical category; due to a reduction in the volume of incomplete capital investments (reduction in the period of discharging investment means); due to hastening the delivery of loads with their transfer to a road with an improved pavement; thanks to the improvement in the activity of the industrial plant and the rural economy (using the given road) as a result of ahead-of-schedule improvement of the conditions of transferring their loads; thanks to improving the distance of the hauling of rapidly-spoiling loads, the absence of delays in hauling in the growing period and a series of other factors.

Below, a method is shown for determining the economic effectiveness of ahead-of-schedule completion of the construction of highways of the national economy with consideration of the first two factors.

The economic effectiveness in the sphere of transport expenditure from ahead-of-schedule introducing the road of a higher technical category, as a rule with an improved pavement, expressed in percents of the estimated cost P_4, is determined according to the formula

$$P_4 = \frac{100 Q_1 L (C_1 - C_2) t}{S_0}, \qquad (187)$$

where Q_1 is the mean freight traffic of the road in t.km/km for the first year of its use; L-is the road length, km; C_1, C_2 is the average weighed cost price of conveyance 1 t.km in rubles along roads with pavements of lower and higher types (existing earlier and constructed again); t is the reduction in construction time in fractions of a year; S_0 is the estimated cost of a road, rubles.

The average freight traffic of the road is determined according to the data of the technical-economic survey. Moreover, it is necessary to take into account the incomplete capacity of the road in the first year of exploitation, especially great with introduction of the road into use along parts. In the absence of the required information, the CoyuzDorNII recommends taking the intensiveness of traffic in the initial period of exploitation in the limits of 20-40% of the prospective for a given road category.

The net cost of transferring may be taken according to Table 61 (SoyuzDorNII doctoral science candidate N.F. Xoroshilov).

Table 61

Category of the road and type of pavement	Relief acc. to traffic conditions		
	Flatlands or parts near to it	Difficult parts of inter-sections	Difficult mountain sections
	Price 1 t.km, kopek		
Ist and IInd category of road with pavement			
Improved main	4-2.5	4.5-3	5-3.5
Improved alleviated	4.5-3	5-3.5	7-4
IIIrd category of roads with pavements			
Improved main	4.5-3	5-3.5	7-4
Improved alleviated	5-3.5	6-4	9-5
Transitional	6-4.5	8-5	10-7
IVth and Vth category of road with pavement			
Improved alleviated	6-4.5	7-5	9-6
Transitional	8-5	9-6	12-7
Lower type (for summer conditions)*	10-6	12-7	15-8

*To obtain the average yearly cost price of hauling along roads with pavements of the lower technical types, the data of this table must be multiplied by the coefficient 1.15-2.00 (for a detailed selection of the coefficient see VSN 120-65).

The cost price of the hauling can be taken according tolTable 61 (SoyuzDorNII, candidate for doctoral science N.F. Xoroshilov).

The economic advantage of transferring traffic onto a road with a move improved type of pavement may be not only after giving up all the roads in use (or individually a large part of it). The transportation organizations reduce the cost of hauling and with partial use of the finished part of the road in the process of its construction, if it is organized by a continuous flow method and theaactual introduction into use of small finished parts is accomplished systematically as they are ready.

With a reduction in the construction periods for the roads, the national economy also obtaines an economic advantage from the reduction in the volume of unfinished capital investments (reduction in the discharge period of investment means).

The economic effectiveness of reducing the volume of unfinished capital investments in percentages of the estimated cost of construction P_5 is determined by thefformula

$$P_5 = \frac{E\,(K_{\text{н}}T_{\text{н}} - K_{\text{ф}}T_{\text{ф}}) \cdot 100}{S_0}, \qquad (188)$$

where E is the standard coefficient taken in the sphere of construction not less than 0.12. If a concrete period of compensation is determined for a given road T, the value $E = 1/T$; S_0 is the estimated cost of construction, rubles; K_H, K_ϕ is the standard and actual (or planned) extent of the investment means for the construction period; T_H, T_ϕ is the standard and actual construction period in years.

The standard values T_H and K_H are taken according to the standards of the construction period and the distribution of capital investments according to years and quarters, confirmed by the Gosstroem SSSR.

The average standard and actual (or planned) amounts of invested capital K_H and K_ϕ for the construction period is calculated according to the formulas:

$$K_{\text{н}} = \frac{K_1 + K_2 + \ldots + K_n}{n}, \tag{189}$$

$$K_{\phi} = \frac{K_1' + K_2' + \ldots + K_n'}{n'}, \tag{190}$$

where K_1, K_2, ..., K_n are cumulative totals of capital investments (according to the standards), to the end of the first, second and all subsequent quarters for the period of construction, rubles; K_1', K_2'. ..., K_n' are the actual (or planned) cumulative totals to the end of each quarter, rub.; n is the number of quarters for the construction period according to the standards; n' is the number of quarters of the actual (or planned) construction period.

The equation characterizing the total economic effectiveness for the national economy for the production of road-construction work and shortening the construction time has the form:

$$Э_{\text{н.х}} = P_1 + P_2 + P_3 + P_4 + P_5 - \mu, \tag{191}$$

where $Э_{H.X}$ is the coefficient of economic effectiveness of road-construction work, determined for the national economy and expressed in percentages of the estimated cost of constructing the road; P_1, P_2, P_3, P_4, P_5 are the economic effect from the carrying out of road-construction work in the winter time, determined according to the formulas (181), (183), (185), (187) and (188) in percentages of the estimated cost; μ is the winter rise in price of the works, also in percentages of the estimated cost of the road.

The carrying out of work in the winter time is advantageous for the national economy only in the case where $Э_{H.X}$ has a positive value.

In the projects of the building organization and for the carrying out of work, it is necessary to determine the economic effectiveness of the construction of prefabricated pavements in the course of the entire year, or only in the winter period (in combination with the construction of monolithic pavements in winter) for the constructional organization $Э_s$ as well as for the national economy $Э_{H.X}$.

With the detailed calculation of the economic effectiveness of the organization of work in the construction of prefabricated pavements, it is necessary to take into account all the factors making the carrying out of the work more expensive and cheaper. Sometimes, local individual special features of the constructional objects may have decisive importance, not considered in the formulas given above.

In individual cases, the technical advantage of prefabricated pavements may turn out to be quite considerable, which can be advantageously used in construction even under conditions which the presented expenditures, determined by calculation on their construction will be a large expenditure on the building of monolithic pavements. In the practice of road construction, such cases are encountered more frequently with the construction of prefabricated pavements and bases in cities. Under conditions of intense traffic and the impossibility of discontinuing it for a long period, the installation of prefabricated pavements, characterized by small volumes of work directly at the place of laying by the capability of immediately letting traffic through, is an optimum variation. The possibility of repeatedly dismantling prefabricated pavements (bases) and after completing the work of underground lines, assembling them again, it no less important for city construction.

The economic advantages obtained by shortening the interruptions of traffic are not always taken into account with sufficient accuracy. However, in cases of a high traffic intensity, the disadvantages from simple transportation or from traffic around disadvantageously constructed detours reach considerable dimensions. The use of rapidly installed prefabricated pavements facilitates reducing these disadvantages.

With the final solution of problems in the organization of the constructional work of prefabricated pavements, it is necessary to also take into account the presence of all the conditions for carrying out the work: 1)the development of bases of the constructional industry in the region of road construction; 2) the actual system of supplying the required materials; 3) the composition, number and technical condition of the fleet of constructional machines (primarily laying machines); 4) the number and load capacity of available transport means; 5) the qualifications of the constructional teams, etc.

39. Technical-Economic Characteristics of Prefabricated Pavements of City Roads

Networks of sanitary-technical and some other designations are frequently laid under the travelled part of streets and under the sidewalks which must be dug up frequently in the propess of their use. Thus, construction of prefabricated pavements and bases on city streets must make it possible to dig them up and lay them again. Prefabricaged concrete pavements are difficult to restore after digging a trench to lay or to repair underground networks. It is practically impossible to resotre prestressed slabs. Thus, when installing concrete pavements, and especially pavements from prestressed, reinforced slabs, the underground engineering-sanitary networks must be placed under sidewalks, under green planted sections, in drainage channels. In this case, tunnels are constructed for laying underground networks in transverse direction, as well as through and semi-through channels.

It is more rational to place the underground networks in underground general reservoirs. They make it possible to lay, replace and repair all types of pipelines and cables without digging up the surface of the street.

It is necessary to take the following into account when planning the placement of underground networks, and constructions under streets with road pavements made of prefabricated, large-dimensioned elements: the technological special features of using each type of underground network and construction; the requirement of public welfare, organizations and use of city streets; the expediency of common laying of different networks in one trench; the abbreviation of the length of transverse branches. To handle this correctly, it seems advisable not to place underground networks under the land occupied with passing traffic.

It is also advisable to construct prefabricated pavements from prestressed reinforced slabs on intersections in two levels. Such pavements may be constructed on streets with continuous traffic.

In individual cases, because of different planning or other conditions, the placement of underground networks under the travelled part or under sidewalks is unavoidable. Then, the pavements on secondary streets or sidewalks are expediently constructed of small-dimensioned slabs which may be used repeatedly in the case of excavations.

The economic effectivness of using prefabricated concrete and reinforced concrete pavements on city streets and sidewalks with the possibility of using them repeatedly after excavation, with laying or repairing underground networks can be determined according to the formula:

$$t \geqslant \frac{100}{n} \cdot \frac{C_{\text{сб}} - C_{\text{м}}}{C_{\text{м}} - \frac{mC_{\text{сб}}}{100}}, \qquad (192)$$

where t is the minimum time (in years) in which it will be justified using prefabricated pavements; n is the average annual percent of excavation on a given street (square, sidewals); C_{CB} is the original cost of a unit of area of prefabricated pavement; C_M is the initial cost of a unit of area of monolithic pavement, m is the percent of circulation of prefabricated pavements (slab losses with dismantling); on the basis of experience it is possible to take m = 17% by way of orientation.

It is especially necessary to note the economic effectivness of using road slabs combined with ancurbe which makes it possible to avoid labor-consuming and unnecessary mechanization work in installing the concrete curbs. (see Table 62).

Table 62

Characteristics	Monolithic concrete pavement with ordinary concrete curb	Prefabricated pavements of reinforced slabs with a curb	In per cents to the concrete pavement
Weight of the design, t	603	313	52
Labor consumption of the construction, men-days	156		
Construction cost, rubles	9860	7100	72
Length 66 the junctions, m	506	150	30

The tendency to ever increasing use of prefabricated elements from reinforced concrete is observed in the construction and capital repair of streetcar lines. The use of ordinary reinforcedcconcrete did not give a proper economic effect due to its poor crack resistance, low resistance to the impact of load and relatively small service life (10-12 years). Prestressed reinforced concrete makes it possible to donawaycwith the noted shortcomings and increase the economic effectiveness of reinforced concrete bases.

Table 63 presents data making it possible to evaluate the effectiveness of the different types of industrial designs of streetcar lines.

As a basis we take the designs of streetcar lines on a crosstie-sand base with wooden impregnated crossties. As is seen from the table, prefabricated designs of the black type and framework cross ties are more economical.

40. Technical-Economic Indicators of Prefabricated Pavements on Temporary Roads

Accomparison of the economic indicators of the different types of prefabricated pavements of temporary (mainly dirt) roads is given according to the results of their use in constructing one of the main highways. The cost of the work in preparing andllaying reinforced concrete gauge pavements with a thickness of 16 cm amounts to 17.55 thousand rubles on 1 km of a one-way road.

The expenditures are composed of the following elements:

1) cost of the slabs manufactured on the polygon with its forces on imported crushed rock 15.4 thousand rubles.

2) the cost for construction on a sandy base 0.54 thousand rubles.

3) the cost of transporting the slabs from the place of manufacture (loading and unloading) to the places they are laid at a mean distance of 25 km--1.38 thousand rubles;

4) the cost of laying the slabs in the pavement 0.23 thousand rubles.

Total 17.55 thousand rubles.

(1) Type of construction
(2) Constructional cost of 1 km of streetcar track, rubles.
(3) Exploitational costs 1 km of track, rubles/year
(4) Deduction for amortization
(5) Constmuctional cost, %
(6) rubles/year
(7) planned preventive repair, rubles/year
(8) ongoing repair and maintenance
(9) % of constructional cost, rubles/year
(10) rubles/year
(11) Total exploitational cost, rubles/year
(12) Difference of the expenditures for different designs of streetcar paths compared with expenditures for cross-tie bases with wooden crossties.
(13) according to constructional cost, rubles/year
(14) according to exploitational cost, rubles/vear
(15) Compensation dates, year
(16) Coefficient of effectiveness

Crosstie-sand base with wooden impregnated crossties.

Sand base with framework, reinforced concrete crossties with prestressed reinforcements

Sand base with frame-panel crossties with prestressed reinforcement

Crosstie-sand base with reinforced concrete crossties and a prestressed reinforcement

Prefabricated reinforced concrete designs of streetcar paths with combined system (foundation and traveling slab of the pavement)

Prefabricated reinforced concrete designs of streetcar paths of the block type.

ТАБЛИЦА 63

(1) Тип конструкций	(2) Строительная стоимость 1 км трамвайных путей, руб.	(3) Эксплуатационные затраты 1 км пути, руб/год					(11) Сумма эксплуатационных затрат, руб/год	(12) Разность затрат на различные типы конструкций трамвайных путей по сравнению с затратами на шпало-песчаные основания с деревянными шпалами		(15) Срок окупаемости годы	(16) Коэффициент эффективности
		(4) амортизационные отчисления		(7) планово-предупредительный ремонт, руб/год	(8) текущий ремонт и содержание						
		(5) % строительной стоимости	(6) руб/год		(9) % от строительной стоимости, руб/год	(10) руб/год		(13) по строительной стоимости, руб/год	(14) по эксплуатационным затратам, руб/год		
Шпало-песчаное основание с деревянными пропитанными шпалами	48 132	7,6	3658	768	8	3851	8277	—	—	—	—
Песчаное основание с рамными железобетонными шпалами с предварительно напряженной арматурой . . .	54 416	5,4	2711	485	7	3515	6711	+6284	—1566	4	0,25
Песчаное основание с рамнопанельными железобетонными шпалами с предварительно напряженной арматурой	55 209	5,4	2981	461	7	3864	7306	+7077	—571	7,3	0,14
Шпало-песчаное основание с железобетонными шпалами и предварительно напряженной арматурой	53 852	5,4	2908	585	7	3770	7263	+5720	—1014	5,6	0,18
Сборные железобетонные конструкции трамвайных путей комбинированной системы (лежень и путевая плита покрытия)	57 074	5,4	3082	529	6	3424	7035	+8942	—1242	7,2	0,14
Сборные железобетонные конструкции трамвайных путей блочного типа	55 412	5,4	2992	233	5	2771	5996	+7280	—2281	3,2	0,31

With the relaying of the slabs, their initial cost is almost fully recurrent: the losses in extremely heavy ground conditions amounts to 9.2%, with each relaying. It should be noted that reinforced concrete slabs of pavements withstand 10-15 and more relayings.

The cost of 1 km of a one-way, gauge road with a pavement of reinforced concrete slabs, with calculation of their relaying, amounted to 3.01 thousand rubles.

The expenditures are made up of the following elements:
1) Expenditure of the pavement 9.2% = 15.4 x 0.09-1.42 thousand rubles.
2) Dismantling and transportation of the slabs (loading and unloading) at a distance of 15 km--0.82 thousand rubles.
3) Construction of the sand base--0.54thhousand rubles.
4) Laying of the slabs in the pavement00.23 thousand rubles.
Total 3.01 thousand rubles.

Under these conditions, the cost of the other types of pavement amounted to:
of the gravel 4.0-4.5 thousand rubles;
of the gravel-crushed rock 5.0-7.0 thoudand rubles;
of the beam-gauge 6.0-6.5 thousand rubles.

Thus, the transition to the construction of temporary tracked roads with a pavement of reinforced concrete reduces their cost compared with wooden gauge or gravel-crushed rock pavements 1.5-2 times.

On the temporary roads examined in the example of construction up to the introductionoof reinforced concrete pavements there was an overconsumption of fuel in the amount of 17.9%, and with the transition to prefabricated pavements an economy of 1.05% was reached. Only in the course of one year of use of reinforced gauge pavements was there a drop in the cost of automobile transportation by 25 thousand rubles. Thus, the dimension of the economy in transport expenditures exceeded the cost of the original expenditures in manufacturing the pavements of prefabricated reinforced concreee slabs.

The economic practicality of using prefabricated-sectional pavements on temporary roads turns out to be higher than the greatest number of times they were relaid from one access to another and lower than the original cost of the slabs. The cost of manufacturing the reinforced concrete slabs shown above of 15.4 thousand rubles was in the case of crushed rock imported from afar, with an increased cost of the sand and manufacturing the slabs on a constructed polygon. As a result, the cost of 1 m^3 of reinforced concrete items turned out to be equal to 70 rubles.

At the present time, the distribution cost of 1 m^3 of the examined slabs for the IIIrd region is 33 rubles, 70 kopeks,* and the cost of manufacturing and laying the reinforced concrete gauge pavements amounted to 11,465 thousand rubles per 1 km of one-day road and consisted of the expenditures shown in Table 54.

*Price list No. 06-08. Wholesale prices for reinforced concrete itema. M., 1967

The comparatively constant expenditures with the construction of roads from reinforced concrete slabs may be: the initial transportation 6fothe slabs from the plant to the construction region 400-500 km along a railroad, and then automobile transport 15-20 km to the place of laying; subsequently, with each relaying on a new place, the distance of the transportation amounts to not more than 15 km.

Table 64

Rate of wages	Type of work	No. of measuring units	Price per unit, rubles	Cost, thousand rubles
32-109 and price list 3 part 1	Construction of sand underlying layer H = 15 cm with transportation of the sand a distance of 5 km, m^3	700	1-25	0.875
32-211 and price list 06-08	Construction of a gauge, reinforced concrete pavement with transportation of the slabs a distance of 25 km, m	240	35-21	8.45

Total direct expenditures	9.325
Applied expenditures	1.49
Total	10.815
Planned accumulation	0.65
Total	11.465

Under these conditions, in the case of 10-15 slab relayings on new approach paths, the cost of 1.0 km of pavement (including the cost of the slabs, their transportation, dismantling and assembly, exploitational expenditure and also preparing the base) amounts to about 2.3 thousand rubles. Such good economic indicators can be attained, as noted,above, by providing multiple use of the pavement slabs. The slabs pay for themselves in 1.5-2 years and the more rapidly the more intense the traffic on them.

In the forest industry, the expenditures for reinforced concrete pavements amount to rubles per 1 km:

Cost of pavement slabs with calculation of

10 fold use	943.0
Expenditures for transporting from the manufacturing plant to the place they are laid	176.0
Preparing the base	247.0
Laying the pavement	329.0
Dismantling and transporting the pavement	869.0
Cost of the connecting devices	40.0
Total	2604.0

Moreover, as in the first case, the maximum setting off of the slab with each relaying has been introduced into the calculation, consisting of the most difficult conditions 10% (from 8.1 to 12.5%). Under normal conditions of use, this setting off does not exceed 2.9-4.1%.

Moreover, the cose of transporting 1 m^3 of wood per 1 km is lowered to 0.6 kopeks compared with a gravel road and 2.4 kopeks compared with a wooden pavement.

The cost of constructing the pavement of temporary roads depends on the cost of the materials, the general cost of the pavement and its general weight, reflected in the amount of transport expenditures. Basic data are given below on the listed characteristics for 1 km of pavement of steel, light alloys and synthetic materials (plywood). The cost of materials (in the numerator) and the cost of pavement (in the denominator) in thousands of rubles consist of: from steel 10/36, from aluminum alloys 66/100 and from plywood 17/38. The weight of 1 km of a one-way gauge pavement consist: of steel---120 t, of aluminum alloys--55 t, of plywood 100 T.

The listed cost data make it possible to give an approximate economic evaluation of the different types of pavement for the concrete case in accordance with the required exploitation times, the volume of transportation and local conditions.

The economic practicality of using prefabricated pavements of temporary roads is confirmed also by the drop in labor expenditures for their construction.

The main factor of economic practicality of temporary roads is the general improvement in the activity of the plant as a whole due to providing it steady work, i.e. work without supply interruptions and also due to the essential improvement in the work of automobile transportation, fuel economy, rubber savings and the improvement in the periods of time between automobile repairs.

APPENDIX

Table 1.--Calculated elasticity moduli of the ground

Road-climate zone	Type of locality	Groups of grounds			
		Sandy loams light and optimum mixtures	Sand, dusty Heavy loam	Light and heavy sandy loam and clay	Sandy loam and heavy, dusty loam
			Calculated modulus of elasticity, kg/cm^2		
			Relative humidity		
			Relative humidity		
			Relative humidity		
			Relative humidity		

Note: Lower values of the elasticity modulus must be assumed for recesses and for zero points. The larger values of the moduli correspond to hoppers.

Table 2.--Poisson coefficients of the grounds.

Names of the grounds	Poisson coefficient
Sandy	
Sandy loam and loam	
Clay	

ПРИЛОЖЕНИЕ

ТАБЛИЦА 1

Расчетные модули упругости грунтов

Дорожно-климатическая зона	Тип местности	Группы грунтов: супеси легкие и оптимальные смеси	пески пылеватые, супеси тяжелые	легкие и тяжелые суглинки и глины	супеси пылеватые и тяжелые, пылеватые суглинки
		Расчетные модули упругости, $кГ/см^2$			
		Относительная влажность 0,65—0,85			
II	1	750—550	700—500	650—460	600—400
	2	550—460	500—370	400—310	400—250
	3	460—370	370—310	310—270	250—200
		Относительная влажность 0,60—0,80			
III	1	900—750	850—700	800—640	750—600
	2	750—550	700—500	640—460	600—400
	3	550—430	500—370	460—310	400—250
		Относительная влажность 0,60—0,75			
IV	1	900—750	850—700	800—650	750—600
	2	750—600	700—560	650—520	600—470
	3	600—500	560—450	520—400	470—400
		Относительная влажность 0,55—0,70			
V	1	1300—900	1200—850	1100—800	1000—750
	2	900—750	850—680	800—620	750—560
	3	750—600	680—560	620—520	560—480

Примечание. Меньшие значения модулей упругости следует принимать для выемок и нулевых мест. Большие значения модулей соответствуют насыпям.

ТАБЛИЦА 2

Коэффициенты Пуассона грунтов

Наименование грунтов	Коэффициент Пуассона
Песчаные	0,30
Супесчаные и суглинистые	0,35
Глинистые	0,40

Table 3.--Elasticity modulus of road-constructional materials

No.	Name of the materials	Dynamic elasticity modulus, kg/cm^2	Note
1.	Crushed rock from mountain rock 1-2 class, processed with viscous bitumen in a device, lower layer asphalt-concrete		Larger values with 3-5°, smaller ones with 10-12°
2.	Gravel processed with viscous bitumen in a device		Same
3.	Gravel procesed with liquid bitumen		
4.	Crushed rock laid according to the principle of wedging, from mountain rock of 1-2 class		
5.	Same, from mountain rock, class 3		
6.	Crushed rock and gravel material, laid without wedging		
7.	Crushed rock (gravel) processed with cement		
8.	Ground, processed with cement		
9.	Bands Fine-grainedd Medium-grained Large grained Gravelly		

Table 4.--Value of the coefficient ψ

Values of the coefficient ψ where α_a, kg/cm^2

Note:

where

2. With values of α larger than 0.80, ψ is assumed to be equal to 1.

ТАБЛИЦА 3

Модули упругости дорожно-строительных материалов

№ п. п.	Наименование материалов	Динамический модуль упругости, $кГ/см^2$	Примечание
1	Щебень из горных пород 1—2 класса, обработанный вязким битумом в установке, нижний слой асфальтобетона	22 000—30 000	Большие значения при 3—5°, меньшие при 10—12° С
2	Гравий, обработанный вязким битумом в установке	14 000—20 000	То же
3	Гравий, обработанный жидким битумом	9 000—14 000	»
4	Щебень, уложенный по принципу заклинки, из горных пород 1—2 класса	5 000— 6 000	»
5	То же, из горных пород 3 класса . .	3 000— 5 000	
6	Щебеночный и гравийный материал, уложенный без заклинки	2 000— 4 000	
7	Щебень (гравий), обработанный цементом	7 000—10 000	
8	Грунт, обработанный цементом . . .	3 000— 6 000	
9	Пески:	1 500— 2 500	
	мелкозернистый	1 500— 1 800	
	среднезернистый	1 800— 2 100	
	крупнозернистый	2 100— 2 300	
	гравелистый	2 300— 2 500	

ТАБЛИЦА 4

Значения коэффициента ψ

α	Значения коэффициента ψ при σ_a, $кГ/см^2$					
	1000	1250	1500	2000	2500	3000
0,85	—	—	—	—	—	0,39
0,06	—	—	—	—	0,40	0,57
0,07	—	—	—	—	0,49	0,68
0,08	—	—	—	0,40	0,63	0,75
0,10	—	—	0,40	0,56	0,76	0,86
0,125	—	—	0,47	0,73	0,85	0,91
0,15	0,47	0,44	0,63	0,82	0,90	0,94
0,20	0,71	0,65	0,78	0,90	0,94	0,97
0,30	0,81	0,82	0,88	0,94	0,97	0,98
0,40	0,85	0,88	0,92	0,96	0,98	0,99
0,50	0,90	0,90	0,93	0,96	0,98	0,99
0,60		0,93	0,95	0,97	0,98	0,99

Примечание:

1. $\alpha = \frac{3F_a E_a}{10 h_0 E_б}$; $\sigma = \frac{M_{расч}}{F_a h_0 \eta}$.

[illegible]	0,1	0,2	0,3	0,4	0,5	0,6	0,8	1,0
[illegible]	0,86	0,82	0,79	0,77	0,75	0,73	0,71	0,69

2. [illegible] ψ принимается равным 1.

Table 5

Name of the characteristic	Designation	Value of the characteristic with the planned concrete brand with elongation at bend, kg/cm^2
		Planned concrete brand, compression strength
Standard resistance to axial compression (strength kg/cm2).		
Standard resistance to compression, kg/cm^2		
Standard resistance to elongation at bend, kg/cm^2		
Standard resistance to elongation, kg/cm^2		
Initial elasticity modulus of the concrete, kg/cm^2		

Table 6

Type of stress resistance	Designation	Calculated resistances of the concrete with the planned concrete brand according to elongation at bend strength, kg/cm^2
		Planned concrete brand according to compression strength
Axial compression (strength)		
Compression at bend		
Axial elongation		
Elongation at bend		
Elongation with calculation for the formation of cracks		
Elongation when checking the necessity of calculating expansion of cracks		

ТАБЛИЦА 5

Наименование показателя	Обозначение	Величины показателей при проектной марке бетона на растяжение при изгибе, кГ/см²							
		20	25	30	35	40	45	50	55
		Проектная марка бетона по прочности на сжатие							
		100	150	200	250	300	350	400	500
Нормативное сопротивление осевому сжатию (призменная прочность), кГ/см²	$R^{н}_{пр}$	80	115	145	175	210	245	280	350
Нормативное сопротивление сжатию при изгибе, кГ/см²	$R^{н}_{и}$	100	140	180	215	260	305	350	440
Нормативное сопротивление растяжению при изгибе, кГ/см²	$R^{н}_{ри}$	20	25	30	35	40	45	50	55
Нормативное сопротивление растяжению, кГ/см²	$R^{н}_{р}$	10	12,5	15	17,5	20	22,5	25	27,5
Начальный модуль упругости бетона, кГ/см²	$\frac{E_б}{10^5}$	1,9	2,3	2,65	2,9	3,15	3,3	3,5	3,8

ТАБЛИЦА 6

Вид напряженного состояния	Обозначения	Расчетные сопротивления бетона при проектной марке бетона по прочности на растяжение при изгибе, кГ/см²							
		20	25	30	35	40	45	50	55
		Проектная марка бетона по прочности на сжатие							
		100	150	200	250	300	350	400	500
Сжатие осевое (призменная прочность)	$R_{пр}$	44	65	80	105	130	150	170	200
Сжатие при изгибе . .	$R_{и}$	55	80	100	130	160	185	210	250
Растяжение осевое . .	$R_{р}$	4,5	5,8	7,2	8,8	10,5	11,5	12,5	14
Растяжение при изгибе	$R_{ри}$	14	17,5	21	24,5	28	31,5	35	38,5
Растяжение при расчете по образованию трещин . . . ; Растяжение при проверке необходимости расчета по раскрытию трещин . . .	$R_{т}$	6,3	8	10	12,2	14,5	16	17,5	19,5

Table 7.--Calculated resistances of a high-strength reinforcing wire and reinforcing bundles with a calculation for strength

Type of reinforcement	Wire diameter, mm	calculated reinforcement resistances, kg/cm^2		
		longitudinal, transverse and bent with calculation for bend along inclined cross section	transverse, and bent with calculation for transverse force	With compression
		elongated		
1. Smooth, high-strength wire acc. to GOST 7348-63				For all types of reinforcements; with cohesion of the reinforcement with the concrete $R_{a.s}$= 3600; with the absence of cohesion of the reinforcement with the concrete;
2. High-strength wire, of irregular profile acc. to GOST 8480-63				
3. Seven-wire reinforcement bundle acc. to CHMTU/TSNIICHM 426-61				

Table 8.--Calculated resistances of a reinforcement with a strength calculation

Type of reinforcement	Calculated resistances of the reinforcement, kg/cm^2		
	longitudinal, transverse and bent with a bend calculation along an inclined cross section	Transverse and bent with a calculation for transverse force	
	elongated		Compression
1. Round (smooth) hot-rolled steel class A-I, and also strip, carbon and plywood of steel brand group St. 3			
2. Hot-rolled steel of periodic profile class A-II			
3. Same, class A-III			
4. Same, class A-IV			
5. Drawn, reinforced steel class A-IIB:			
a) with a check for stresses and elongation			
b) with a check of elongation only			

ТАБЛИЦА 7

Расчетные сопротивления высокопрочной арматурной проволоки и арматурных прядей при расчете на прочность

Вид арматуры	Диаметр проволоки, мм	Расчетные сопротивления арматуры, кГ/см²: растянутой — продольной, поперечной и отогнутой при расчете на изгиб по наклонному сечению	растянутой — поперечной и отогнутой при расчете на поперечную силу	сжатой $R_{а.с}$
1. *Проволока* высокопрочная гладкая по ГОСТ 7348—63	3	12 200	9700	Для всех видов арматуры: при наличии сцепления арматуры с бетоном $R_{а.с}=3600$; при отсутствии сцепления арматуры с бетоном $R_{а.с}=0$
	4	11 500	9200	
	5	10 800	8600	
	6	10 200	8100	
	7	9 600	7600	
	8	8 900	7100	
2. Проволока высокопрочная периодического профиля по ГОСТ 8480—63	3	11 500	9200	
	4	10 800	8600	
	5	10 200	8100	
	6	9 600	7600	
	7	8 900	7100	
	8	8 300	6700	
3. Семипроволочные арматурные пряди по ЧМТУ/ЦНИИЧМ 426—61	1,5	12 200	9700	
	2	11 500	9200	
	2,5	11 500	9200	
	3	10 800	8600	
	4	10 200	8100	
	5	9 600	7600	

ТАБЛИЦА 8

Расчетные сопротивления арматуры при расчете на прочность

Вид арматуры	Расчетные сопротивления арматуры, кГ/см²: растянутой — продольной, поперечной и отогнутой при расчете на изгиб по наклонному сечению	растянутой — поперечной и отогнутой при расчете на поперечную силу	сжатой $R_{а.с}$
1. Сталь горячекатаная круглая (гладкая) класса А-I, а также полосовая, угловая и фасонная группы марок сталь Ст. 3	2100	1700	2100
2. Сталь горячекатаная периодического профиля класса А-II	2700	2150	2700
3. То же, класса А-III	3400	2700	3400
4. То же, класса А-IV	5100	4100	3600
5. Сталь упрочненная вытяжкой класса А-IIВ:			
а) с контролем напряжений и удлинений	3700	3000	2700
б) с контролем только удлинений	3250	2600	2700

Table 8 (continued)

6. Same, class A-IIIb
a) With a check of stresses and elongation
b) with a check of only elongation

7. Ordinary reinforcing wire (with the use in welded networks and frameworks):

a) Diameter from 3 to 5.5 mm
b) Diameter from 6 to 8 mm

Продолжение табл. 8

Вид арматуры	Расчетные сопротивления арматуры, $кГ/см^2$: растянутой продольной, поперечной и согнутой при расчете на изгиб по наклонному сечению	поперечной и отогнутой при расчете на поперечную силу	сжатой $R_{а\cdot с}$
6. То же, класса A-IIIв:			
а) с контролем напряжений и удлинений	4500	3600	3400
б) с контролем только удлинений	4000	3200	3400
7. Проволока арматурная обыкновенная (при применении в сварных сетках и каркасах):			
а) диаметром от 3 до 5,5 *мм* . .	3150	2200	3150
б) диаметром от 6 до 8 *мм* . . .	2500	1750	2500

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